

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-271 076

**Nonpoint Sources: An Assessment of
Pollutant Loadings to Lakes and Rivers
in North Central Texas**

North Central Texas Council of Governments, Arlington

Jun 77

PB 271 076

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SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET		1. Report No. NCTCOG/WR-77/05	2.	3. Recipient's Accession No.	
4. Title and Subtitle Nonpoint Sources: An Assessment of Pollutant Loadings to Lakes and Rivers in North Central Texas				5. Report Date June 1977	
				6.	
7. Author(s) Hydroscience, Inc.; Arlington, Texas				8. Performing Organization Rept. No.	
9. Performing Organization Name and Address Prepared for: North Central Texas Council of Governments P.O. Drawer COG Arlington, Texas 76011				10. Project/Task/Work Unit No.	
				11. Contract/Grant No. P-006038-01-0	
12. Sponsoring Organization Name and Address U.S. Environmental Protection Agency Region VI Dallas, Texas 75201				13. Type of Report & Period Covered	
				14. 906/004	
15. Supplementary Notes Part of an areawide water quality management planning process under Section 208 of PL 92-500.					
16. Abstracts This report provides an initial assessment of the magnitude of nonpoint sources of water pollution in the Dallas/Fort Worth Designated Planning Area. This presentation is intended to provide a perspective regarding the relative magnitude of the various major nonpoint sources and the relative importance of these nonpoint sources when compared with point sources in the area. Three major nonpoint source categories are emphasized: runoff from urban areas, runoff from grassland, and runoff from cropland. The four major pollutants of concern are five-day biochemical oxygen demand, total nitrogen, total phosphorus, and sediment.					
17. Key Words and Document Analysis. 17a. Descriptors Nonpoint Sources, Nonpoint Loadings, Runoff, Urban Runoff, Agricultural Runoff, Stormwater, Rainfall Analysis, Areawide Assessment, 208 Planning, Water Quality Impacts					
17b. Identifiers/Open-Ended Terms North Central Texas, Dallas/Fort Worth Area, Trinity River, 208 Planning, Areawide Assessment, Water Quality Management					
17c. COSATI Field Group					
18. Availability Statement Unlimited Release sponsored by EPA				19. Security Class (This Report) UNCLASSIFIED	
				21. No. of Pages 159	
				20. Security Class (This Page) UNCLASSIFIED	
				22. Price PCA08 MF A01	



June 30, 1977

Mr. Herman Veselka, P.E.
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Dear Mr. Veselka:

We are pleased to submit herewith our report entitled "Nonpoint Sources: An Assessment of Pollutant Loadings to Lakes and Rivers in North Central Texas." This report is an interim output in partial fulfillment of our contract with the North Central Texas Council of Governments for the study of nonpoint sources in the Dallas/Fort Worth Designated Planning Area. This report has been produced to provide estimates of the magnitude of major nonpoint sources of water pollution. These results are presented for interim information purposes and for the setting of priorities during the remaining phases of the nonpoint source studies.

We wish to thank the NCTCOG staff for their cooperation in this portion of the study. Significant contributions have been made by Charles Bayer, John Promise, Hal Jennings, and Tom Shelton. We also acknowledge the substantial contributions of Claudia Zahorcak and Walter Chiang of our staff.

Respectfully submitted,

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ACKNOWLEDGEMENTS

This project is funded through a planning grant from the U.S. Environmental Protection Agency under provisions of Section 208 of Public Law 92-500. The work has been supervised by the Department of Water Resources of the North Central Texas Council of Governments (NCTCOG) under the direction of Herman J. Veselka.

Hydroscience wishes to gratefully acknowledge the contributions to this study by Charles Bayer and John Promise of the NCTCOG staff. Extensive land use information was developed for this study by Jim Parr, Hal Jennings, Tom Shelton and the staff at the Department of Management and Planning Coordination at NCTCOG. Additional land use information was provided by Bob Price and Mike Rysinger of the Denton Office of the U.S. Soil Conservation Service. Hydroscience also wishes to express its appreciation to Kristy Libotte of the NCTCOG staff for the cover design and special graphics provided for this report.

The primary author of this report was Jonathan Young. Substantial engineering analysis was provided by Claudia Zahorcak and additional engineering calculations were provided by Walter Chiang and Roger Segura. Alan Plummer provided coordination and review throughout the study. Graphical displays were produced by William Wallace and typing by Anne Lemmons. Much of the methodology applied in the urban stormwater analysis is based on previous work by Dominic DiToro and Mitchell Small of the Hydroscience staff.

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The purpose of this report is to provide an initial assessment of the magnitude of nonpoint sources of water pollution in the Dallas/Fort Worth Designated Planning Area. This presentation is intended to provide a perspective regarding the relative magnitude of the various major nonpoint sources when compared with point sources in the area.

The calculations presented in this interim report are based upon data which were immediately available from local reports and national literature. All values are subject to change and many will be modified to varying degrees as a result of ongoing data collection and analysis efforts. The goal of the present report is to provide order of magnitude estimates of nonpoint sources for interim information purposes and for the setting of priorities during the remaining phases of the nonpoint source studies. A refined assessment of these values will be available in the final report for this contract, which is due in the Fall of 1977 and will be incorporated by the North Central Texas Council of Governments (NCTCOG) into its 1978 Annual Water Quality Management Plan.

The major emphasis of the present report is directed at three nonpoint source categories: runoff from urban areas, runoff from grassland, and runoff from cropland. In this initial assessment, the four major pollutants of concern are five-day biochemical oxygen demand (BOD₅), total nitrogen (N), total phosphorus (P), and sediment. In this terminology, the word "pollutant" is used in a general sense, simply meaning some material which is added to the water.

The findings of this initial assessment are summarized below:

Land Uses

1. The Planning Area includes a region of 8744 square kilometers. This area includes approximately 50% grassland, 23% cropland, 23% urban area, and 4% water surface.
2. This Planning Area can be conveniently divided into regions which contribute pollutants to the major lakes, including Lakes Worth, Benbrook, Arlington, Mountain Creek, Grapevine, Lewisville, Lavon and Ray Hubbard, and regions which contribute pollutants to the major river sections, such as the Elm Fork, East Fork, West Fork, and main stem of the Trinity River.

Point Sources

1. Municipal wastewater treatment plants are the only significant point sources of pollution to public waterways in the Planning Area. Approximately 95% of these pollutants are discharged into the river sections downstream of the major lakes.
2. In the 1975-1976 period, referred to as "Condition 1," point sources contributed approximately the following pollutant loads within the Planning Area:

BOD₅ = 18.6 million kg/yr
Nitrogen = 10.1 million kg/yr
Phosphorus = 3.8 million kg/yr
Total Suspended Solids = 20.9 million kg/yr

Treatment plant improvements recommended in NCTCOG's "1977 Annual Water Quality Management Plan for North Central Texas" should reduce the BOD₅ and TSS discharges to approximately the following levels:

BOD₅ = 4.1 million kg/yr
TSS = 4.1 million kg/yr

These improvements, referred to as "Condition 2," will represent a decrease in BOD₅ and TSS to values which will be 22% and 20%, respectively, of the 1975-1976 point source loading levels.

Urban Stormwater

1. Analysis of twenty-four years of hourly rainfall records for the rain gage at Dallas Love Field indicate that the Planning Area receives an average of approximately 86 storms per year, of which approximately 26 occur during the nominally "dry" summer period of June, July, August, and September. The average rainfall volume is 1 centimeter per storm.
2. On an annual average basis, approximately 35% of the rain falling on urban areas within the Planning Area becomes direct runoff. This runoff carries significant amounts of pollutants to local lakes and rivers.
3. Based on local data and data in national literature, the following annual average pollutant loads were estimated for urban stormwater runoff in the Planning Area:

BOD₅ = 5.9 million kg/yr
Nitrogen = 1.5 million kg/yr
Phosphorus = 0.3 million kg/yr
Sediment = 257.0 million kg/yr

4. After the waste treatment plant improvements are complete, it is estimated that more than 35% of the storms will generate urban stormwater loads of BOD₅ which will exceed the daily BOD₅ loads from all point sources in the Planning Area.

Rural Loadings

1. Land which is used for cropland generally introduces a larger amount of pollutants to rural runoff than does the same size area of grassland. Available local and national data were used to estimate the amount of pollutants contributed by grassland and cropland in the Planning Area; these values can be summarized as follows:

BOD ₅ :	Grassland = 4.8 million kg/yr
	Cropland = 5.1 million kg/yr
Nitrogen:	Grassland = 600 thousand kg/yr
	Cropland = 910 thousand kg/yr
Phosphorus:	Grassland = 55 thousand kg/yr
	Cropland = 79 thousand kg/yr
Sediment:	Grassland = 280 million kg/yr
	Cropland = 2.7 billion kg/yr

2. From local data, preliminary estimates can be made of the approximate levels of pollutant loading which would exist in the absence of all human activity in the Planning Area. These background loads can be summarized as follows:

BOD ₅ =	7 million kg/yr
Nitrogen =	610 thousand kg/yr
Phosphorus =	61 thousand kg/yr
Sediment =	350 million kg/yr

These estimates will be refined during the remainder of the study period.

Comparisons Between Sources

1. From the calculations presented thus far, it is possible to provide a comparison between the major sources of BOD₅, nitrogen, phosphorus, and sediment. Five major sources are included in this comparison: point sources, urban stormwater, grassland, cropland, and sources outside the Designated Planning Area. A summary of the total pollutant loads and the approximate percentages contributed by each source is presented in Table ES-1.
2. During the 1975-1976 period (Condition 1), point sources were the predominant contributors of BOD₅ to the Planning Area. These point sources generated approximately 39% of the total annual load of BOD₅.

TABLE ES-1

ESTIMATED SOURCES OF ANNUAL POLLUTANT LOADS
DALLAS/FORT WORTH DESIGNATED PLANNING AREA

	APPROXIMATE TOTAL LOAD (MILLION KG/YR)	POINT SOURCE	URBAN STORMWATER	GRASSLAND	CROPLAND	FROM OUTSIDE PLANNING AREA
BOD ₅ CONDITION 1	47	39%	12%	10%	11%	28%
BOD ₅ CONDITION 2	33	12%	18%	15%	16%	39%
NITROGEN	15	68%	10%	4%	6%	12%
PHOSPHORUS	4.4	87%	7%	1%	2%	3%
SEDIMENT	6,800	0.3%	5%	4%	39.7%	51%

3. Many improvements to the municipal waste treatment plants in the Planning Area are presently under construction, as discussed in NCTCOG's 1977 Annual Plan. When these improvements are completed (Condition 2), the point source contribution of BOD₅ will be reduced to approximately 12% of the total annual load. At that time, nonpoint sources within the Planning Area and sources outside the Planning Area will be the predominant contributors of BOD₅ on an annual basis.
4. When compared with other sources of nutrients, point sources within the Planning Area are the major contributors of these pollutants. At present, these municipal waste treatment plants contribute approximately 68% of the nitrogen and 87% of the phosphorus.
5. Within the Planning Area, cropland appears to be the predominant contributor of sediment, accounting for approximately 40% of this pollutant. Most of the remaining sediment load, approximately 51%, is generated by sources outside and upstream of the Planning Area.

Water Quality Impacts

1. In the absence of human activity in an area, some pollutant material would still be transported in the runoff from the land surface. Certain amounts of these substances are needed to sustain life in water bodies. Human activities tend to add significant amounts of material to the runoff in addition to these background levels. The activities may cause significant degradation of the quality of the receiving bodies of water. This degradation must be judged relative to naturally occurring conditions, the intended use of the water body, aesthetics, and the existing water quality standards.
2. Some of the major impacts of pollution in the Planning Area appear to be severe oxygen depletion in local rivers, accelerated eutrophication in some local lakes and rivers, export of nutrients to water bodies downstream of the Planning Area, accelerated rates of sedimentation in several local lakes, and high coliform levels in local rivers. Other pollutants whose impact need additional study include heavy metals and other toxicants such as pesticides. The relative roles of point and nonpoint sources in these water quality problems will be investigated by NCTCOG and their consultants during the 1977-1978 planning cycle.

3. Other sources of pollutants in the Planning Area include landfills, septic tanks, feedlots, resource extraction, and construction. Although these sources may cause localized pollutant problems, it is anticipated that their overall effect is small when compared with the major point and nonpoint sources.

CHAPTER I
INTRODUCTION

CHAPTER I

INTRODUCTION

A. Purpose of the Report.

The purpose of this report is to provide an initial assessment of the magnitude of nonpoint sources of water pollution in the Dallas/Fort Worth Designated Planning Area under Section 208 of Public Law 92-500. This presentation is intended to provide a perspective regarding the relative magnitude of the various major nonpoint sources and the relative importance of these nonpoint sources when compared with point sources in the area.

The calculations presented in this interim report are based on data which were immediately available from local reports and national literature. All values are subject to change and many will be modified to varying degrees as a result of ongoing data collection and analysis efforts. The goal of the present report is to provide order of magnitude estimates of nonpoint sources for interim information purposes and for the setting of priorities during the remaining phases of the nonpoint source studies. A refined assessment of these values will be available in the final report for this project which is due in the Fall of 1977. These reports on nonpoint sources will provide basic information to other contractors who, in turn, will determine the associated water quality impacts and appropriate control strategies.

B. Study Approach.

The term "point source" is generally applied to direct discharges of wastewater from municipal and industrial water and wastewater treatment plants and from electric power generation facilities. As indicated in previous studies,⁽¹⁾ municipal wastewater treatment plants are the only significant point sources of pollution to public waterways in the Dallas/Fort Worth Designated Planning Area; daily and annual pollution loads from these plants are used in this report for comparison with nonpoint sources.

The term "nonpoint sources" is generally applied to all water pollution sources not included by the term "point sources." Many of these "nonpoint sources" are related to the runoff from rainfall events; these type of nonpoint sources will receive the major emphasis in this report and include three categories: runoff from urban areas, runoff from grassland, and runoff from cropland. Oftentimes, other special categories are also grouped under the term "nonpoint sources" and these categories will be discussed only briefly in this report; these special categories include septic tanks, land disposal sites, construction, resource extraction, and feedlots.

The four major pollutants of concern in this initial assessment are 5-day biochemical oxygen demand (BOD₅), total nitrogen (N), total phosphorus (P), and sediment. In most of the load calculation in this study, the terms "sediment" and "total suspended solids" are considered to

be essentially equivalent; however, it should be recognized that the term "sediment" is generally applied to suspended solids which originate from the erosion of soils, whereas the term "total suspended solids" is generally applied to suspended solids which include a substantial amount of organic material derived from biochemical reactions. Other parameters, such as bacteria, pesticides, and heavy metals are also discussed briefly in this initial assessment, although less information is available on the magnitude of the local nonpoint sources of these materials.

In the assessment of pollutant loads associated with runoff events, several levels of detail can be addressed.⁽²⁾ As illustrated in Figure I-1, runoff pollutant loads can be assessed on an "annual" basis (Level 1), a "per storm" basis (Level 2) or a "variation within a storm" basis (Level 3). Of these three levels of detail, generally only the first two levels are appropriate for an initial assessment and will be the only levels addressed by this report. Level 3 assessments are generally appropriate for more detailed design studies and when extensive data on a wide variety of individual storms are available.

An important consideration in determining the required level of analytical detail is the areal extent and length of time over which the anticipated water quality impacts are expected to occur. A Level 1 assessment is appropriate for those parameters which are expected to have distributed effects on an annual or seasonal basis. Examples of these

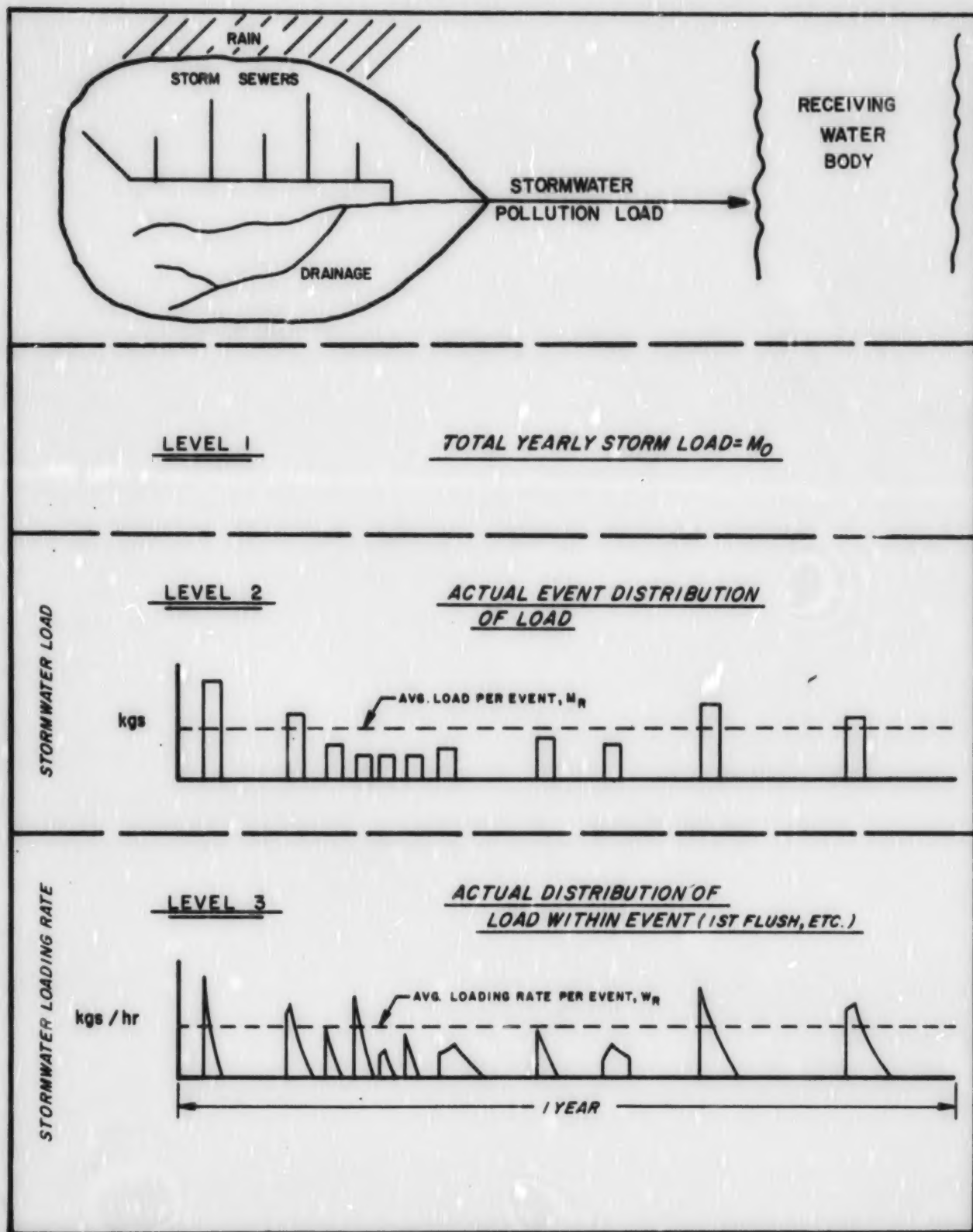


FIGURE I-1
 VARIOUS LEVELS OF DETAIL IN
 STORMWATER LOAD CHARACTERIZATION

effects would include eutrophication caused by high levels of nutrients in runoff or the long-term buildup of toxic substances in the receiving water bodies. A Level 1 analysis is also appropriate for comparisons between annual runoff loads and annual loads discharged from point sources.

Level 2 analyses include a more thorough investigation of the distribution of the pollution loads among storms. In this level of assessment, the number of storm events are determined as well as the frequency with which various magnitudes of loadings can be expected. This approach is particularly useful for the estimation of loading values which are associated with individual storm impacts, such as elevated BOD levels and resulting dissolved oxygen depressions in the receiving body of water.

This report is organized with the following sequence of topics:

1. area description
2. land use categorization
3. point source description
4. estimation of urban stormwater
pollutant loadings
5. estimation of rural runoff
pollutant loadings
6. comparison between the various
point and nonpoint sources and
7. description of potential impacts

The nonpoint loadings presented in this report are to be considered as initial estimates which are subject to revision as a result of the ongoing sampling activities and other

portions of the areawide water quality management planning efforts in the Dallas/Fort Worth region. As many local data sets as possible have been incorporated into these estimates; however, some reliance had to be placed on literature values available from studies in other areas.

The intent of this report is to provide an initial overview of the magnitude of nonpoint sources and the report, therefore, includes only a minimal amount of technical explanations regarding the calculations involved. Methodologies will be provided in subsequent reports to the North Central Texas Council of Governments as part of the 1977-1978 annual planning cycle.

All values presented in this report are expressed in the units of the metric system. A table of conversion factors for English units is provided in an appendix to the report.

CHAPTER 12
AREA DESCRIPTION

CHAPTER II

AREA DESCRIPTION

A. Presentation Areas.

For the purposes of the Dallas/Fort Worth Areawide Water Quality Management Planning efforts, the Designated Planning Area has been divided into seven major watersheds which have been labelled "presentation areas." These presentation areas are shown in Figure II-1 and can be described as follows ⁽¹⁾:

Presentation Area A - West Fork Lakes. Includes those watersheds within the Designated Planning Area which drain to Lake Worth, Lake Benbrook, Lake Arlington, and Mountain Creek Lake.

Presentation Area B - Elm Fork Lakes. Includes those watersheds within the Designated Planning Area which drain to Lake Grapevine and Lake Lewisville.

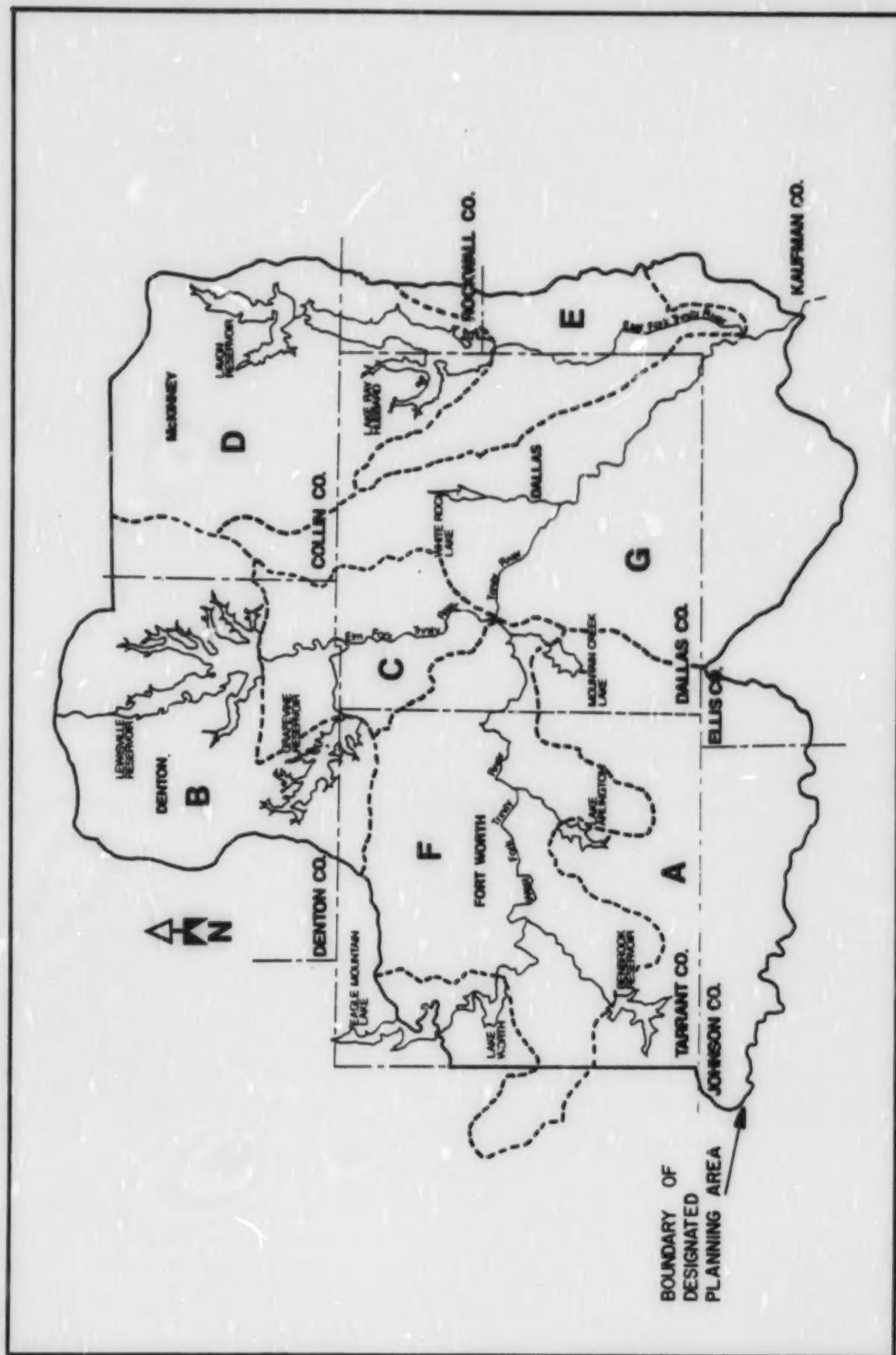
Presentation Area C - Elm Fork Below Lakes. Includes the Elm Fork drainage area below Lakes Grapevine and Lewisville.

Presentation Area D - East Fork Lakes. Includes the watersheds within the Designated Planning Area which drain to Lake Lavon and Lake Ray Hubbard.

Presentation Area E - East Fork Below Lakes. Includes the East Fork drainage area below Lake Ray Hubbard.

Presentation Area F - West Fork Below Lakes. Includes the drainage area to the Trinity River below Lakes Benbrook, Worth, Arlington, and Mountain Creek.

Presentation Area G - Trinity River. Includes the drainage area to the main stem of the Trinity River below the West Fork.



B. Lakes.

The lakes in the Planning Area are of major concern with regard to the impact of point and nonpoint pollution sources. A description of the major lakes in the Planning Area is provided in Table II-1. As can be seen from this table, a significant amount of the drainage to most of these lakes is derived from areas upstream and outside of the Planning Area.

C. Streams.

The impact of point and nonpoint pollution on streams is also a major concern of the ongoing water quality management planning program. A summary of the data from major stream gages in the Planning Area is provided in Table II-2. The flows in these streams are significantly controlled by the operation of the dams in the area. Furthermore, at low flow conditions, the flows in several streams are made up almost exclusively of waste treatment plant discharges.

D. Land Use Categories.

In order to provide the basis for detailed calculations, the seven presentation areas were divided into eighty-one sub-basins. Through an extensive effort by the NCTCOG staff and the Soil Conservation Service, these eighty-one sub-basins were then evaluated according to thirty-nine land use categories. A summary of these categories is shown in Table II-3. These land uses provide the basis for the estimates of runoff characteristics

TABLE II-1
PLANNING AREA LAKE DATA

<u>NAME</u>	<u>PRESENTATION AREA</u>	<u>SURFACE AREA (km²)</u>	<u>TOTAL DRAINAGE AREA (km²)</u>	<u>PERCENT DRAINAGE AREA IN PRESENTATION AREA</u>
Lake Worth	A	14.4	5346	3
Lake Arlington	A	9.2	370	100
Benbrook Lake	A	15.3	1110	28
Mountain Creek Lake	A	11.0	764	100
Lake Lewisville ¹	B	94.2	4299	23
Grapevine Lake	B	29.9	1800	12
Lake Ray Hubbard	D	92.0	2782 ²	49 ⁴
Lake Lavon	C	86.6 ³	1990	23
White Rock Lake	G	4.5	259	100

¹Formerly Garza-Little Elm Reservoir or Lake Dallas, before enlargement (capacity reached 1951).

²Includes Lake Lavon and its drainage area.

³At capacity (presently being filled).

⁴100% of drainage area downstream of Lake Lavon is included.

TABLE II-2
PLANNING AREA STREAMFLOW DATA

STREAM	GAGE NUMBER	LOCATION	PRESENTATION AREA	DRAINAGE AREA (km ²)	PERCENT IN PRESENTATION AREA	MEAN DISCHARGE (m ³ /sec)	PERIOD EVALUATED*	SOURCE OF INFORMATION
West Fork		Eagle Mountain Lake release	A	5102	0	7.03	CY 1975-1976	Tarrant County Water Control and Improvement District No. 1.
Elm Fork	08050500	near Sanger (upstream of Lake Lewisville)	B	987	0	4.36	WY 1949-1975	USGS
Elm Fork		Lake Lewisville release	C	4299	24	23.0	CY 1973-1976	U.S. Army Corps of Engineers.
Denton Creek		Grapevine Reservoir release	C	1800	11	5.09	CY 1973-1976	U.S. Army Corps of Engineers.
Elm Fork	08055500	near Carrollton (below Denton Creek, 29 km upstream from mouth)	C	6369	24	26.48	CY 1972-1973	USGS and City of Dallas
East Fork	08059000	near McKinney (above Lake Lavin)	D	492	25	3.26	WY 1949-1975	USGS
East Fork	08061000	near Lavon (1000 m downstream of dam)	D	2002	29	11.33	WY 1953-1975	USGS
East Fork		Lake Ray Hubbard release	E	2782	49	21.01	CY 1973-1977	City of Dallas
East Fork	08062000	near Crandall (18 km upstream from mouth)	E	3253	56	26.99	CY 1972-1975	USGS
West Fork		Lake Worth release	F	5346	3	2.69	CY 1973-1976	Tarrant County Water Control and Improvement District No. 1.
Clear Fork		Benbrook Reservoir release	F	1110	28	2.95	CY 1973-1976	U.S. Army Corps of Engineers
West Fork	08048000	at Fort Worth (downstream from Clear Fork)	F	6773	12	10.70	WY 1921-1975	USGS
Village Creek		Lake Arlington release	F	370	100	0.0		City of Arlington
Mountain Creek		Mountain Creek Lake release	F	764	100	4.71	CY 1973-1976	
West Fork	08049500	at Grand Prairie (upstream from Mountain Creek and Elm Fork)	F	1938	25	16.48	CY 1972-1975	USGS
Trinity River	08057000	at Dallas (8 km downstream from confluence West and Elm Forks)	G	15815	31	42.9	WY 1903-1975	USGS
Trinity River	08057410	below Dallas (between White Rock and Five Mile Creek)	G	16260	33	49.5	WY 1957-1975	USGS
Trinity River	08062500	near Rosser (14 km downstream from East Fork)	G	21098	42	96.3	WY 1972-1975	USGS

*CY = Calendar Year; WY = Water Year.

TABLE II-3
LAND USE CATEGORIES

Residential

1. Single Family: Low Density
2. Single Family: Medium Density
3. Single Family: High Density
4. Multi-Family
5. Mobile Home
6. Group Quarters

Commercial

7. Commercial
8. Government
9. Education

Industrial

10. Industry
11. Wholesale Trade

Services

12. Transportation
13. Roadways
14. Utilities

Other Urban

15. Parks and Open Space
16. Urban Vacant

Agricultural

- 17.-19.* Cropland, Row
- 20.-22.* Cropland, Close Growing
- 23.-25.* Cropland, Row with
Cover Crop
26. Pasture, Good Cover
27. Pasture, Poor Cover

Special Agricultural

28. Orchards and Nurseries
29. Feedlots

Rangeland

30. Range, Good Cover
31. Range, Poor Cover
32. Range, Shrub and Brush

Woodlands

33. Hardwoods
34. Juniper

Water

35. Water Areas
36. Wetlands

Resource Extraction

37. Active Strip Mines
38. Inactive Strip Mines

Other Rural

39. Rural Non-Farm

* Each crop category has three management factor subcategories:

- 1 Conservation cropping system--adequate.
- 2 Contouring and terracing only.
- 3 No conservation treatment.

and pollutant generating potential presented later in this report.

For the purposes of this report, these categories were combined into four major land use designations: urban, cropland, grassland, and water. Table II-4 provides a summary of these land uses for the presentation areas. As can be seen from the table, the Planning Area contains approximately 50% grassland, 23% cropland, 23% urban area, and 4% water surface.

TABLE II-4
LAND USE FOR PRESENTATION AREAS*

Letter	PRESENTATION AREA Name	TOTAL AREA km ²	GRASSLAND AREA km ²	CROPLAND AREA km ²	WATER AREA km ²	URBAN AREA km ²
A	West Fork Lakes	1580	979	347	49	205
B	Elm Fork Lakes	1261	813	226	121	101
C	Elm Fork Below Lakes	593	302	79	8	204
D	East Fork Lakes	1355	591	432	186	146
E	East Fork Below Lakes	612	324	157	9	122
F	West Fork Below Lakes	1371	621	145	4	601
G	Trinity River	1972	774	579	13	606
	TOTAL	8744	4404	1965	390	1985
	PERCENTAGE OF TOTAL AREA		50.3%	22.5%	4.5%	22.7%

* Determined from land use values prepared by NCTCOG.

CHAPTER III
POINT SOURCES

CHAPTER III

POINT SOURCES

A. Present Discharges.

Considerable insight can be gained regarding the relative magnitude and potential impact of nonpoint sources by comparing them with existing and future point discharges in the area. At present, twenty-five major waste treatment plants discharge within the Planning Area.⁽¹⁾ A summary of these discharges is provided in Table III-1; this table provides estimates of present discharge flows and concentrations of BOD₅, TSS, nitrogen, and phosphorus. The values for BOD₅ and TSS were determined from self-reporting data⁽¹⁾ from the plants. Estimates for phosphorus and nitrogen were based on a limited number of grab samples from some of the treatment plants;⁽³⁾ for plants for which no data were available, the average values for the plants having data were applied; these values were 27 mg/l for total nitrogen and 10 mg/l for total phosphorus.

The appropriate annual point source loads of BOD₅, nitrogen, phosphorus, and total suspended solids are shown for each of the presentation areas in Table III-2. Approximately 95% of these materials are discharged into Presentation Areas E, F, and G.

B. Alternate Conditions.

Because of the ongoing program for the construction of waste treatment plant improvements, the amounts of BOD₅

TABLE III-1

POINT SOURCE SUMMARIES*
1975-1976 AVERAGES

PLANT	PRESENTATION AREA AND NUMBER	FLOW (m ³ /sec)	BOD ₅ (mg/l)	TSS (mg/l)	ESTIMATED TOTAL P (mg/l)	ESTIMATED TOTAL N (mg/l)
Midlothian	A1	0.009	31.6	72.7	10.0	27.0
Denton	B1	0.276	18.0	39.4	7.8	7.2
Grapevine (Morehead)	B2	0.018	9.5	12.5	10.0	27.0
Lewisville	C1	0.118	70.1	53.0	10.0	27.0
Flower Mound MUD	C2	0.004	3.4	10.7	10.0	27.0
Garland (Rowlett Creek)	D1	0.140	14.1	16.0	10.0	27.0
NTMWD (Plano)	D2	0.136	38.8	47.2	10.0	20.6
McKinney (South)	D3	0.035	24.2	24.0	10.0	27.0
Wylie	D4	0.013	7.4	7.6	11.2	25.8
Rockwall	D5	0.018	6.6	7.1	11.2	24.3
Garland (Duck Creek)	E1	0.736	120.7	52.9	10.0	27.0
NTMWD (Mesquite)	E2	0.215	58.1	50.3	9.4	30.0
Seagoville	E3	0.018	6.2	3.6	10.0	27.0
TRA (Central)	F1	1.915	37.1	85.7	10.3	27.1
Fort Worth (Village Creek)	F2	1.687	14.8	29.3	8.2	17.3
Fort Worth (Riverside North)	F3-N	0.903	28.5	31.1	8.5	30.0
Fort Worth (Riverside South)	F3-S	0.307	37.2	36.5	10.0	27.0
Haltom City	F4	0.022	11.9	19.8	10.0	27.0
Fort Worth Int'l Airport	F5	0.013	8.6	12.7	10.0	27.0
Dallas (Central)	G1	5.232	58.0	57.8	10.1	27.1
Dallas (South Side)	G2	0.232	104.8	100.3	10.0	57.9
TRA (Ten Mile Creek)	G3	0.241	9.8	10.9	12.9	12.6
Richardson (Floyd Branch)	G4	0.061	20.5	19.1	10.0	27.0
Balch Springs (WCID No. 6)	C5	0.035	17.8	42.2	10.0	27.0
Kleberg (WCID No. 7)	G6	0.013	7.8	28.4	10.0	27.0

*References 1 and 3.

TABLE III-2
LOADS FROM POINT SOURCES
1975-1976

PRESENTATION AREA	BOD ₅ (kg/yr)	TOTAL N (kg/yr)	TOTAL P (kg/yr)	TOTAL SUSPENDED SOLIDS (kg/yr)
A	10,000	7,600	2,800	20,000
B	160,000	110,000	74,000	350,000
C	260,000	104,000	39,000	200,000
D	260,000	247,000	109,000	310,000
E	3,200,000	845,000	301,000	1,570,000
F	4,210,000	3,700,000	1,408,000	7,990,000
G	10,470,000	5,066,000	1,855,000	10,450,000
Total	18,570,000	10,079,000	3,788,800	20,890,000

and TSS being discharged within the Planning Area are rapidly changing. An indication of the extent of these changes is provided in Table III-3, which has been derived from a report for the North Central Texas Council of Governments by Camp Dresser & McKee, Inc., and Water Resources Engineers, Inc.⁽¹⁾ This table summarizes the 1975-1976 self-reporting data for the major domestic and municipal treatment plants in the Planning Area. The table also lists the State effluent requirements which are being recommended in the NCTCOG 1977 Annual Plan.

In order to compare point and nonpoint loading levels, three point source loading conditions were calculated for this report that are similar to alternatives which are presently being considered by the Texas Water Quality Board for waste treatment plants in the Planning Area. These conditions can be summarized as follows:

CONDITION 1 (1975-1976 BOD₅ Loading Condition):

Includes the reported 1975-1976 effluent flow quantities and reported 1975-1976 effluent BOD₅ and TSS concentrations (Table III-3).

CONDITION 2

Includes the reported 1975-1976 effluent flow quantities and the effluent BOD₅ and TSS concentrations reported in Table III-3 as the "state effluent requirements." As can be seen in this table, this condition includes effluents of 10 mg/l BOD₅ which are presently being implemented at the following 12 plants: Denton, Lewisville, Garland-Rowlett, NTMWD Plano, McKinney South, Wylie, Garland Duck Creek, NTMWD Mesquite, TRA Central, and Dallas South Side.

TABLE III-3¹

MAJOR DOMESTIC AND MUNICIPAL TREATMENT PLANT DISCHARGES FOR THE PLANNING AREA

PRESENTATION AREA DESIGNATION	STATE EFFLUENT REQUIREMENTS			1975-1976 SELF-REPORTED DATA ³		
	Avg Permit Flow ² (m ³ /sec)	Avg BOD (mg/l)	Avg TSS (mg/l)	Avg Flow (m ³ /sec)	Avg BOD (mg/l)	Avg TSS (mg/l)
A1 Midlothian	0.039	30	30	0.009	31.6	72.7
B1 Denton	0.263	10	15	0.276	18.0	39.4
B2 Grapevine Morehead	0.066	20	20	0.018	9.5	12.5
C1 Lewisville	0.263	10	15	0.118	70.1	53.0
C2 Flower Mound	0.031	5	5	0.004	3.4	10.7
D1 Garland-Rowlett	0.263	10	15	0.140	14.1	16.0
D2 WTMWD (Plano)	0.263	10	10	0.136	38.8	47.2
D3 McKinney South	0.088	10	15	0.035	24.2	24.0
D4 Wylie	0.035	10	15	0.013	7.4	7.6
D5 Rockwall	0.026	20	20	0.018	6.6	7.1
E1 Garland Duck Creek	1.314	10	10	0.736	120.7	52.9
E2 WTMWD (Mesquite)	0.241	10 ⁴	10 ⁴	0.215	58.1	50.3
E3 Seagoville	0.053	20	20	0.018	6.2	3.6
F1 TRA Central	4.380	10	10	1.914	37.1	85.7
F2 Fort Worth - Village Creek	4.205	10	10	1.686	14.8	29.3
F3-N Fort Worth - Riverside North ⁵				0.903	28.5	31.1
F3-S Fort Worth - Riverside South ⁵				0.307	37.2	36.5
F4 Haltom City	0.053	20	20	0.022	11.9	19.8
F5 Fort Worth International Airport	0.022	20	20	0.013	8.6	12.7
G1 Dallas Central ⁴	6.570	10	10	5.230	58.0	57.8
G2 Dallas South Side	0.438	10	10	0.232	104.8	100.3
G3 TRA Ten Mile Creek	0.298	20	20	0.241	7.8	10.9
G4 Richardson Floyd Branch	0.096	20	20	0.096	20.5	19.1
G5 Dallas County WCID No. 6 (Balch Springs)	0.026	20	20	0.035	17.8	42.2
G6 Dallas County WCID No. 7 (Kieberg)	0.022	20	20	0.013	7.8	28.4

¹From Table IV-5 in Reference 1.²Indicates estimate of greatest permitted flow during the year 1977.³Arithmetic average of self-reporting data for the 12-month period of July, 1975 - June, 1976.⁴Value presently requested by Mesquite.⁵Riverside Plant to be phased out, July, 1978.⁶1977 effluent requirements for Dallas Central also include a 3 mg/l Nitrogen (as NH₃) level.

CONDITION 3

Reported 1975-1976 effluent flow quantities and the effluent BOD₅ and TSS concentrations applied in Condition 2 except with six of the treatment plants with a 5 mg/l BOD₅ and 5 mg/l TSS concentration in their effluents. These six plants include Garland Duck Creek, NTMWD Mesquite, TRA Central, Fort Worth-Village Creek, Dallas Central, and Dallas South Side. This condition is one of several options presently being considered for the Planning Area.

The annual BOD₅ and TSS loading rates for these three conditions are summarized for each presentation area in Table III-4.

TABLE III-4
ALTERNATE POINT SOURCE LOADING CONDITIONS

PRESENTATION AREA	DISCHARGED FLOW (m^3/yr)	CONDITION 1 (1975-1976)		CONDITION 2		CONDITION 3	
		BOD ₅ (kg/yr)	TSS (kg/yr)	BOD ₅ (kg/yr)	TSS (kg/yr)	BOD ₅ (kg/yr)	TSS (kg/yr)
A	0.3×10^6	10,000	20,000	10,000	10,000	10,000	10,000
B	9.3×10^6	160,000	350,000	100,000	140,000	100,000	140,000
C	3.9×10^6	260,000	200,000	40,000	60,000	40,000	60,000
D	10.8×10^6	260,000	310,000	110,000	140,000	110,000	140,000
E	30.5×10^6	3,200,000	1,570,000	310,000	310,000	160,000	160,000
F	152.8×10^6	4,210,000	7,990,000	1,540,000	1,540,000	780,000	780,000
G	183.3×10^6	10,470,000	10,450,000	1,940,000	1,940,000	1,080,000	1,080,000
Total	390.9×10^6	18,570,000	20,890,000	4,050,000	4,140,000	2,280,000	2,370,000

CHAPTER IV
URBAN STOPWATCH

CHAPTER IV

URBAN STORMWATER

In an initial assessment, the determination of urban stormwater pollutant loadings can be divided conveniently into four major parts: 1) analysis of rainfall patterns; 2) evaluation of runoff volumes; 3) determination of annual pollutant loads; and 4) calculation of the frequency of occurrence of various size storm loads. This chapter provides the results of these four analyses for the Planning Area.

A. Rainfall Analysis.

An understanding of the rainfall characteristics of a study area is a fundamental requirement for the assessment of stormwater loadings. A thorough analysis of rainfall data for the Dallas-Fort Worth area was undertaken as part of this study. The rain gage at Dallas Love Field was chosen as being appropriate to represent the rainfall characteristics of the Planning Area for the purposes of this report. Twenty-four years of hourly rainfall records were analyzed for the rain gage; this period included approximately 2060 storm events. This analysis will be presented below with a fair amount of detail in order to provide a perspective into the rainfall characteristics of the area as well as a feeling for the frequency with which storms of various magnitudes can be expected.

The variables which are of particular interest in statistical analysis of rainfall are the intensity (cm/hr) of the rainfall, the total volume (cm) of the rainfall for a particular storm event, the duration of the event, measured by the number of hours over which the storm took place, and the interval (hrs) between storms, measured from the midpoint in time of a given storm to the midpoint in time of the next storm. Statistical parameters such as the mean, standard deviation, and coefficient of variation of these four variables can be calculated from a computer analysis of available hourly rainfall data. For this study, a storm event was defined as a period of rainfall succeeded by three consecutive hours of no rainfall. All storm events were extracted from the station's hourly data, and the intensity, volume, duration, and time between storms were calculated. These measurements were grouped by years, and the means and standard deviations were calculated. The results of this analysis are shown in Table IV-1. This table demonstrates the wide range of wet and dry years occurring in the Planning Area.

As seen in Table IV-2, the storms can also be grouped by month; that is, all storms during the period of record which occurred in a given month were grouped and the statistical parameters calculated to indicate monthly trends. This type of presentation provides an indication of monthly and seasonal trends in the rainfall data.

TABLE IV-1
ANNUAL RAINFALL STATISTICS SUMMARY FOR DALLAS

NWS STATION #41 2244										
PERIOD OF RECORD: 1949-1972										
Year	Duration (hrs)		Intensity (cm/hr)		Volume/Storm (cm)		Time Between Midpoints of Storms (hrs)		Total Annual Volume (cm)	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev		
1949	4.3	4.9	0.20	0.26	0.94	2.08	73.	102.	110.5	
1950	3.9	3.2	0.26	0.28	1.12	1.37	96.	145.	98.8	
1951	3.7	3.2	0.26	0.31	0.97	1.50	117.	176.	71.1	
1952	5.0	6.0	0.18	0.23	1.04	1.78	133.	158.	72.1	
1953	4.3	4.1	0.20	0.25	0.81	1.22	119.	138.	61.0	
1954	4.6	5.4	0.22	0.22	0.97	1.27	129.	169.	67.1	
1955	3.7	3.7	0.21	0.23	0.79	0.97	120.	186.	56.9	
1956	4.4	5.8	0.15	0.21	0.89	1.63	142.	194.	55.1	
1957	4.5	4.6	0.21	0.26	1.14	1.83	72.	107.	139.9	
1958	4.9	4.7	0.19	0.32	0.97	1.55	103.	117.	83.6	
1959	3.5	3.8	0.20	0.32	0.89	2.03	78.	110.	99.8	
1960	4.7	4.9	0.23	0.29	1.09	1.70	92.	120.	105.9	
1961	5.1	7.4	0.20	0.24	1.04	1.73	86.	104.	101.6	
1962	4.3	3.9	0.26	0.29	1.24	1.78	173.	335.	65.3	
1963	4.2	5.0	0.19	0.27	0.76	1.17	151.	212.	44.4	
1964	4.6	5.0	0.22	0.32	1.12	1.68	102.	157.	95.3	
1965	4.4	4.9	0.21	0.26	0.97	1.75	96.	121.	90.2	
1966	4.3	3.8	0.28	0.41	1.24	1.75	103.	119.	109.2	
1967	4.6	4.1	0.19	0.27	0.81	1.04	102.	124.	70.6	
1968	4.1	4.8	0.18	0.27	0.71	1.22	69.	81.	91.9	
1969	4.9	5.0	0.21	0.26	1.14	1.91	103.	145.	97.8	
1970	5.4	5.2	0.25	0.29	1.24	1.45	125.	168.	87.1	
1971	3.7	4.0	0.27	0.37	1.12	1.83	94.	118.	104.6	
1972	3.4	3.5	0.22	0.27	0.74	1.24	109.	165.	60.7	
									Average Annual Volume	85.0
									Std Dev	22.7

TABLE IV-2
MONTHLY RAINFALL STATISTICS SUMMARY FOR DALLAS

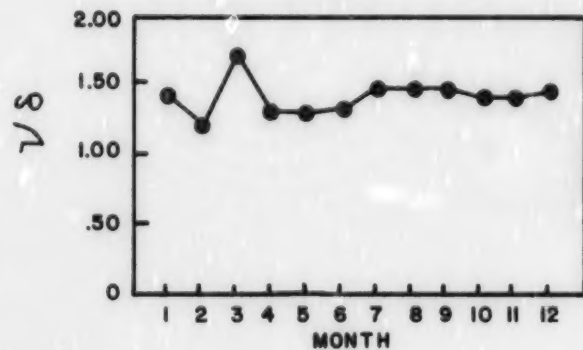
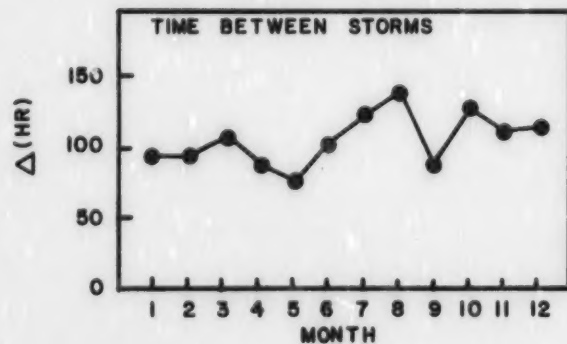
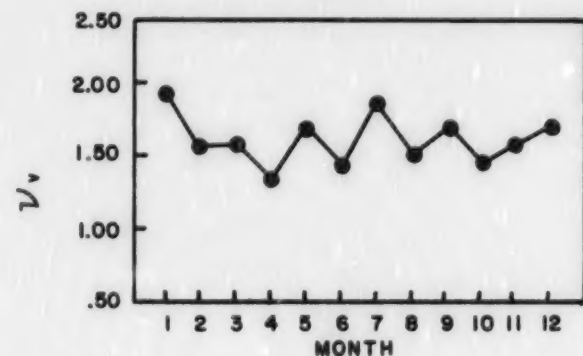
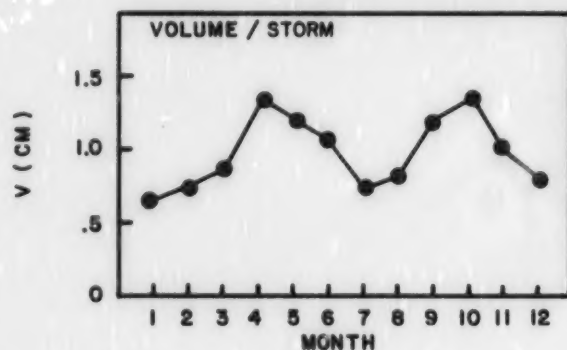
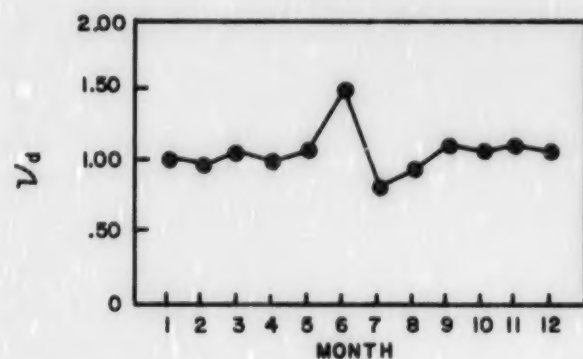
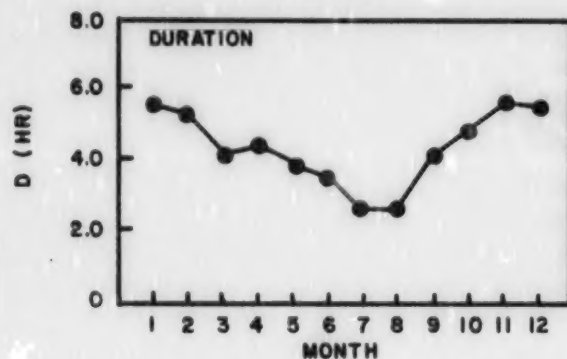
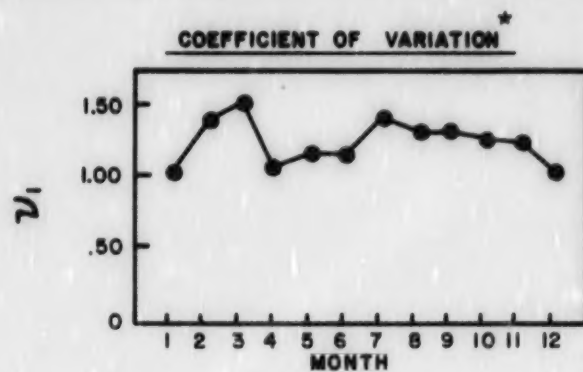
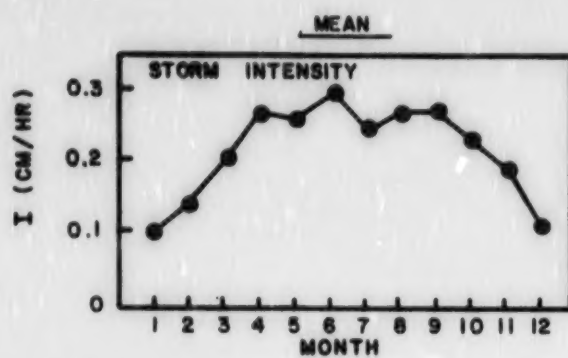
NWS STATION: #41 2244
PERIOD OF RECORD: 1949-1972

Month	Duration (hrs/storm)		Intensity (cm/hr)		Volume/Storm (cm)		Time Between Midpoints of Storms (hrs)	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
January	5.5	5.6	0.10	0.10	0.66	1.92	91.	129.
February	5.3	5.1	0.13	0.18	0.74	1.58	90.	110.
March	4.2	4.4	0.20	0.31	0.84	1.61	108.	183.
April	4.3	4.1	0.27	0.29	1.32	1.35	85.	112.
May	3.9	4.0	0.26	0.30	1.19	1.69	76.	97.
June	3.5	5.2	0.29	0.33	1.07	1.47	104.	136.
July	2.6	2.1	0.24	0.33	0.69	1.84	128.	187.
August	2.6	2.4	0.27	0.35	0.79	1.51	138.	199.
September	4.0	4.4	0.27	0.35	1.17	1.69	88.	128.
October	4.7	4.9	0.23	0.29	1.35	1.47	125.	171.
November	5.6	6.1	0.18	0.22	1.04	1.59	113.	155.
December	5.4	5.6	0.11	0.11	0.79	1.73	115.	160.
OVERALL AVERAGE	4.3	4.5	0.21	0.26	0.99	1.58	102.	142.

These trends can also be seen in Figure IV-1. These calculations indicate a seasonal trend in intensity, with higher intensity storms occurring during the summer months. Duration of events also ranges seasonally, with shorter storms occurring during the mid-summer months. These two trends indicate that shorter but more intense storms are prevalent during the mid-summer, whereas storms during the winter tend to be longer and less intense. The total volumes of the storms vary seasonally as well, with pronounced peaks in the spring and fall. The time between storms is greater for July and August than for the remaining months.

Additional insight into the weather patterns can be gained by summarizing the storm characteristics by month. This type of information is presented in Table IV-3, which shows for each month the average number of storm events, the average rainfall volume, and the average number of hours of rainfall. It is interesting to note that on the average, of the 86 storms which occur in the area per year, approximately 26 occur during the nominally "dry" summer months of June, July, August, and September. These patterns are shown in Figure IV-2.

Two other useful determinations were made for this rain gage record by arranging the storms in order according to the total volume of rainfall during the individual storm events. One type of determination which resulted from this ordering was the frequency of occurrence of storms equal to



* COEFFICIENT OF VARIATION = $\frac{\text{STANDARD DEVIATION}}{\text{MEAN}}$

FIGURE IV-1
MONTHLY RAINFALL STATISTICS

TABLE IV-3

STORM EVENT SUMMARY, DALLAS AREA:
AVERAGE VALUES FOR 1949-1972

<u>MONTH</u>	<u>NUMBER OF STORM EVENTS</u>	<u>RAINFALL VOLUME PER MONTH (cm)</u>	<u>HOURS OF RAINFALL PER MONTH</u>
January	8.2	5.4	45
February	7.5	5.6	39
March	6.9	5.9	29
April	8.5	11.3	37
May	9.8	11.8	38
June	6.9	7.4	24
July	5.8	4.0	15
August	5.4	4.3	14
September	8.2	9.6	33
October	5.9	8.0	28
November	6.4	6.6	36
December	<u>6.5</u>	<u>5.1</u>	<u>35</u>
YEARLY TOTAL	86.0 storms/yr	85.0 cm/yr	373 hours/yr
STORM AVERAGES		.99 cm/storm	4.3 hours/storm

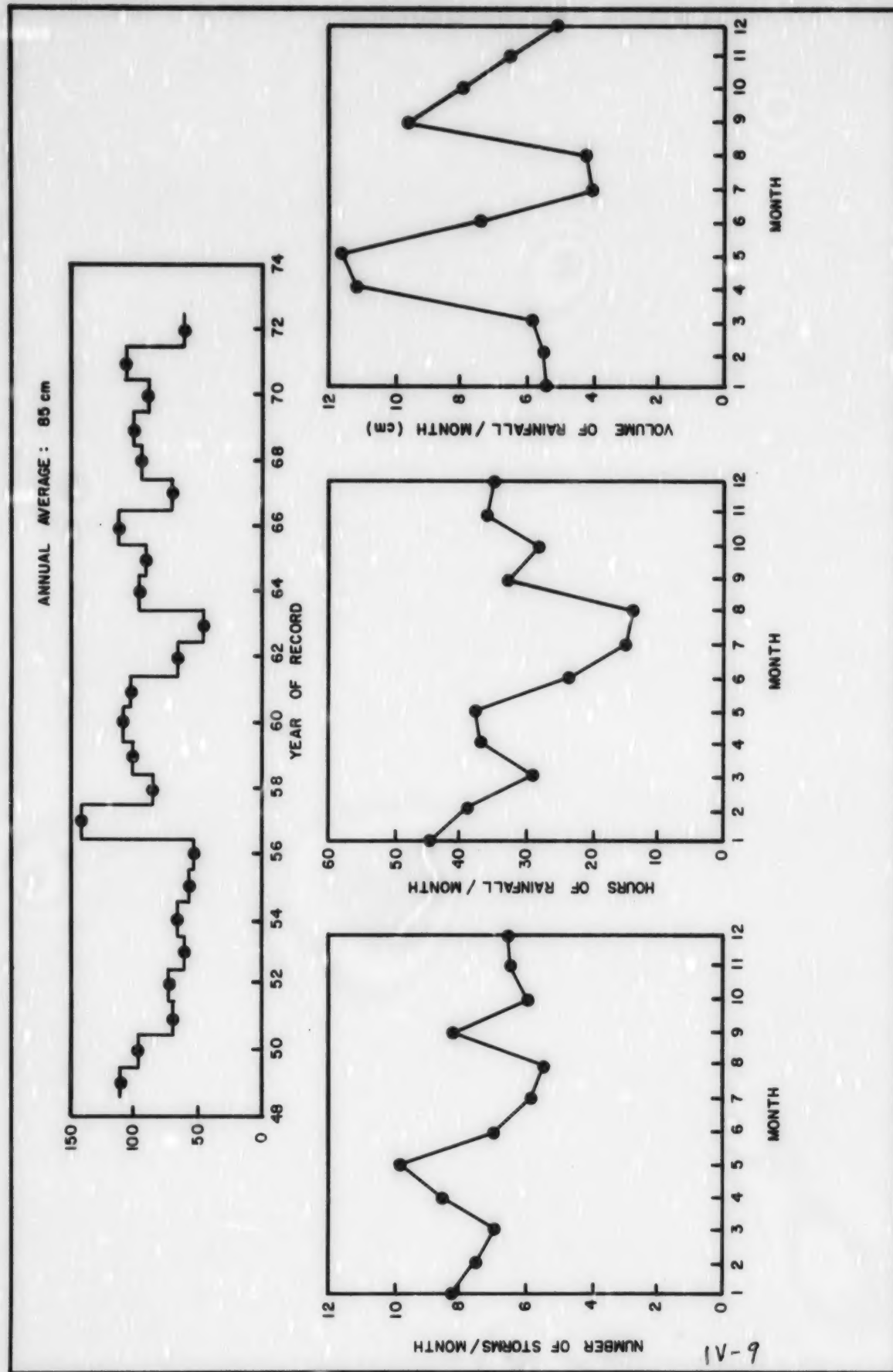


FIGURE IV-2
ANNUAL AND MONTHLY RAINFALL PATTERNS
DALLAS LOVE FIELD RAIN GAGE

or less than a given volume. A second type of determination was the return period which is the time period during which a storm of a given volume is expected on the average to occur only once. These determinations are the result of the analysis of the actual data for the given period of record. This type of analysis is presented in Table IV-4.

The left side of Table IV-4 lists the return period for various storms volumes as recorded by the rain gage during the years 1949 to 1974. For that period, the table shows that the largest storm volume in the 24 years which were analyzed was 15.7 centimeters. The second largest volume was 13.8 centimeters. Further examination of the table indicates that a storm of 7.7 centimeters is the maximum storm which occurred on an average of once every year and that a storm of 2.1 centimeters was the maximum storm which occurred on an average of once a month.

The right side of Table IV-4 lists the frequency of occurrence of storms of various volumes for the analyzed data. As mentioned above, 100 percent of the recorded rainfall volumes for the 24 years were less than or equal to 15.7 centimeters. The table indicates that 99 percent of the storm volumes were less than or equal to 7.8 centimeters, 90 percent were less than or equal to 2.8 centimeters, and 50 percent were less than or equal to 0.33 centimeters. The predominance of small storms is obvious. Furthermore, through examination of the values shown on Table IV-4, it can be seen that approximately 99 percent of the storms

TABLE IV-4

FREQUENCY OF OCCURRENCE AND RETURN PERIOD
FOR STORMS OF A GIVEN VOLUME FOR DALLAS

NWS STATION: #41 2244

PERIOD OF RECORD: 1949-1972

a.) Return PeriodReturn Period
of StormVolume/Storm
(centimeters)

1 month	2.1
3 months	4.4
6 months	5.9
1 year	7.7
2 years	9.0
4.8 years	11.8
6 years	12.6
8 years	13.1
12 years	13.8
24 years	15.7

b.) Frequency of OccurrencePercentage of
Occurrences
Less Than or
Equal ToVolume/Storm
(centimeters)

1	0.028
5	0.033
10	0.043
15	0.053
20	0.069
25	0.089
30	0.12
35	0.17
40	0.20
45	0.26
50	0.33
55	0.43
60	0.61
65	0.76
70	0.97
75	1.2
80	1.6
85	2.0
90	2.8
95	4.2
99	7.8
100	15.7

have a rainfall volume with a return period of one year or less. This means that a very wide variety of storms can be expected in any given year.

Additional perspective can be obtained by examining diagrams which combine information on rainfall volume, duration, and return frequency. Such a diagram was derived for this study and is shown in Figure IV-3. This figure was not determined from data for a single rain gage but is based on the averages of rainfall records from many rain gages in the Planning Area. (4)

B. Runoff Analysis.

The second step in the determination of stormwater pollutant loads is to estimate the runoff quantity. For the purposes of this study, the primary means of calculating runoff quantity will be through the use of the Runoff-to-Rainfall Ratio, R_V .

The function of the Runoff-to-Rainfall Ratio is to estimate the volume of the stormwater runoff generated by rainfall of a known volume. R_V is simply defined as the ratio of the runoff volume from an area to the rainfall volume on that area. This parameter is expressed as a fraction and is most easily calculated by dividing the runoff in centimeters by the rainfall in centimeters. As an example calculation of the Runoff-to-Rainfall Ratio, if 80 centimeters of rain falls on an area in one year and it is determined that 20 centimeters of water has run off that area during the year as a direct result of rainfall events, then the annual average R_V equals 0.25.

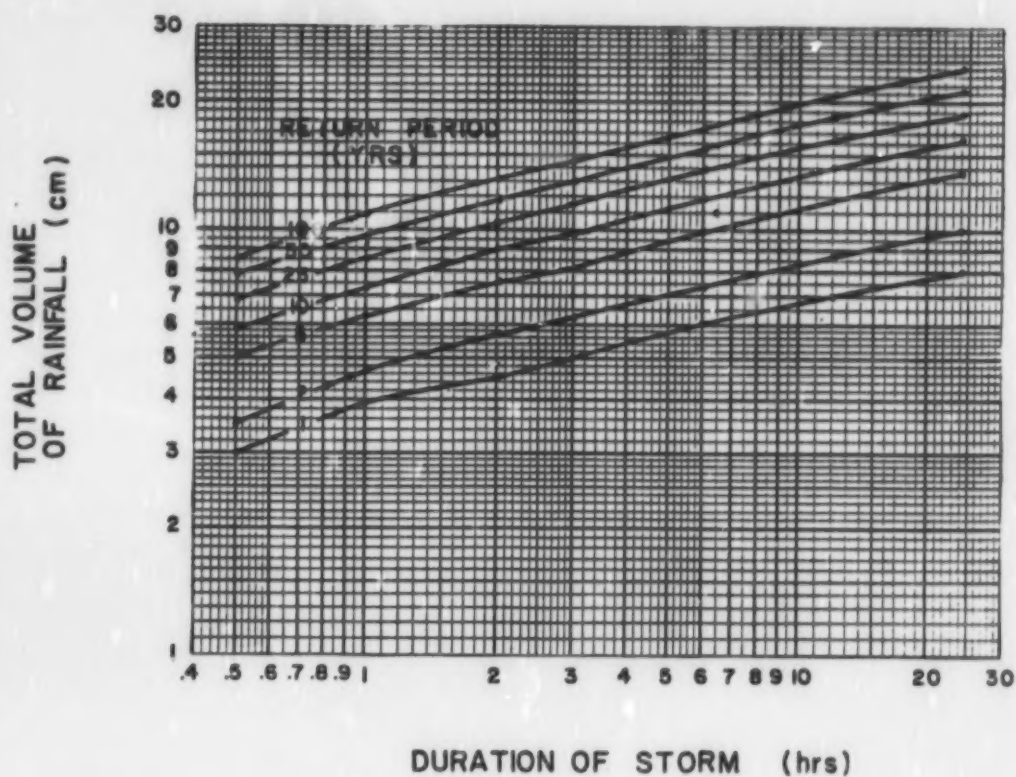


FIGURE IV-3
RAINFALL FREQUENCY CURVES
DALLAS-FT. WORTH AREA

The average value of R_v is primarily determined by five characteristics of the drainage basin.

- Percentage of impervious area
- Soil type
- Soil cover
- Land slope
- General rainfall characteristics

Of these factors, for urban areas the most significant influence on this Runoff-to-Rainfall Ratio is generally the percentage of impervious area in a given drainage basin. An impervious surface, such as a concrete roadway, will prevent the rain which falls on the surface from percolating into the soil. Therefore, the larger the amount of impervious area in a basin, the greater will be the proportion of rainfall which becomes runoff. The percentage of impervious area in a basin depends upon land use patterns and population density. For an initial approximation, the values shown in Table IV-5 may be used.^(2,5) These values agree well with local determinations by the U.S. Geological Survey.⁽⁶⁾ As discussed in Chapter II, an extensive data base is available for the land use characteristics of the Planning Area. The values shown in Table IV-5 were applied to this data base to provide an estimate of the amount of impervious surfaces existing in the urban portions of the study area. In general, the most reliable method for calculating R_v values is to analyze a large number of measured runoff hydrographs which have resulted from

TABLE IV-5

ESTIMATES OF IMPERVIOUS AREA FOR
LAND USE CATEGORIES¹

<u>Land Use Category</u>	<u>Percent Impervious Area</u>	
	<u>Including Roads²</u>	<u>Without Roads</u>
Residential		
Low density; acre lots	20	
Medium density; 1/4 to 1/2 acre lots	40	30
High density; 1/8 acre lots	60	
Multiple-family	70	65
Paved areas, central business district	100	100
Commercial, highly developed	80	75
Industrial, highly developed	70	67
Commercial, moderately developed	60	50
Institutional, public	30	19
Open, undeveloped, with roads	8	0

¹Note: Impervious area includes the street pavements, drive-ways, rooftops, parking lots, sidewalks, and similar surfaces.

²Reference 2.

individual storms in the study area. Fortunately, these types of analyses have been performed on eleven urban areas in Dallas and Fort Worth.^(6,7) Table IV-6 summarizes representative data from six of these areas and the resulting calculated values for the Rainfall-to-Runoff Ratio, R_V .

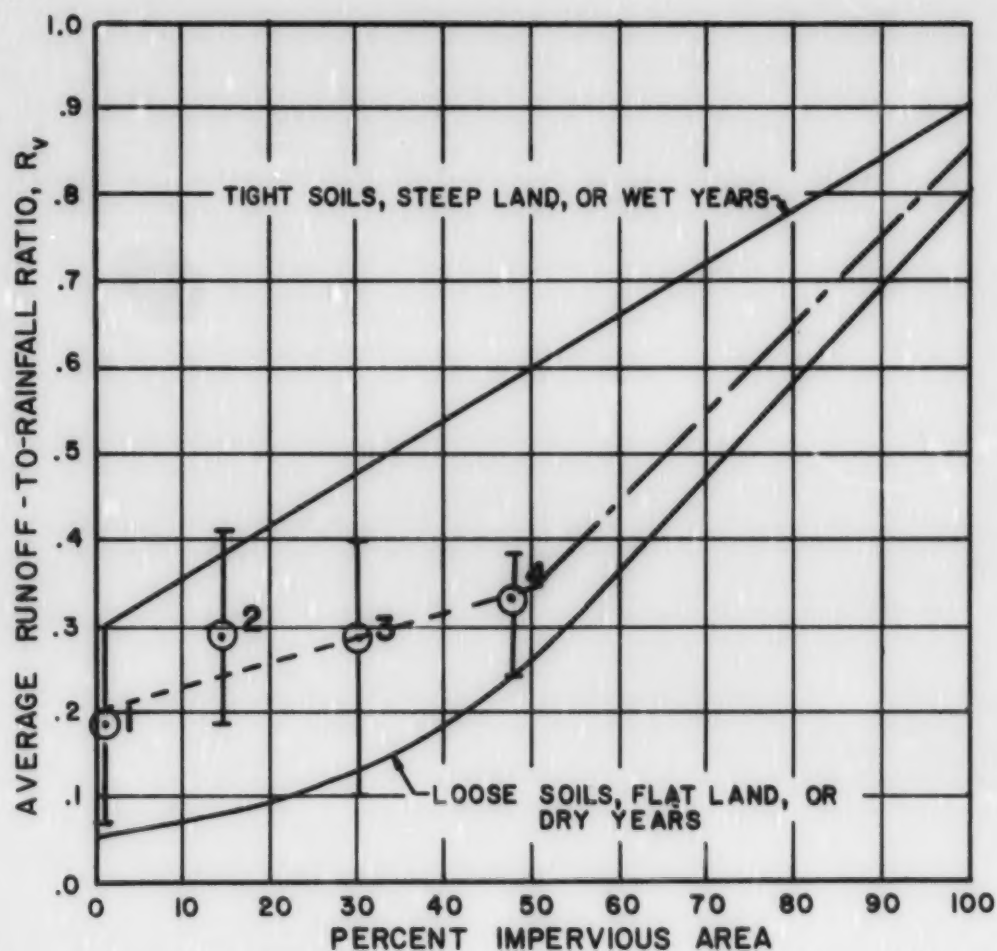
Generalized graphs are available which relate the percentage of impervious area to R_V . An example of this type of graph⁽²⁾ is shown in Figure IV-4 on which the data from the Dallas watersheds in Table IV-6 have been superimposed. The Dallas data shows excellent agreement with the expected range of values. Therefore, the dashed lines shown in the figure were used to estimate the values of R_V for the study area. Based on these R_V values, the average annual runoff for the urban areas in each of the 81 sub-basins in the Planning Area were calculated and then accumulated according to Presentation Area. The results of this analysis are shown in Table IV-7.

C. Annual Loading.

The third step in the determination of stormwater pollutant loads is to evaluate the quality of the stormwater. To fully assess the impact of stormwater events on receiving water bodies, characterization of the amounts of pollutants carried by the stormwater should be made. This characterization can be made on an annual average or single event basis, depending upon the desired level of assessment. The approach which was applied in this initial assessment of urban stormwater loadings in the Planning Area was based

TABLE IV-6
RUNOFF CHARACTERISTICS OF SMALL URBAN WATERSHEDS

LOCATION	AREA (km ²)	DATES	ANNUAL RAINFALL RANGE (cm)	MEAN ANNUAL RAINFALL (cm)	ANNUAL RUNOFF RANGE (cm)	MEAN ANNUAL RUNOFF (cm)	ANNUAL R _v RANGE	MEAN ANNUAL R _v	COMMENTS
<u>Dallas</u>									
White Rock Creek	76.2	1962-70	66-112	94	5-34	17	.07-.30	.16	16 impervious; moderately tight soils; 2-15% slopes.
White Rock Creek	95.8	1962-70	74-122	97	13-51	28	.18-.42	.29	14% impervious; moderately tight soils; 2-15% slopes.
Bachman Branch	25.9	1964-70	66-112	94	6-45	26	.10-.39	.28	30% impervious; moderately tight soils; 2-5% slopes.
Turtle Creek	20.7	1962-70	61-112	94	15-52	32	.24-.38	.34	47% impervious; moderately tight soils; 2-7% slopes.
<u>Fort Worth</u>									
Sycamore Creek	45.8	1971-73	56-107	81	4-23	15	.08-.24	.19	Rural, residential, light industry; tight soils.
Tributary	2.6	1971-73	58-119	84	11-33	22	.20-.31	.26	Residential, park, shopping center; tight soils.



1. UPPER WHITE ROCK CREEK
2. LOWER WHITE ROCK CREEK
3. BACHMAN BRANCH
4. TURTLE CREEK

KEY

— MAXIMUM ANNUAL

○ AVERAGE ANNUAL

— MINIMUM ANNUAL

FIGURE IV-4
RELATIONSHIP BETWEEN
IMPERVIOUS AREA AND RUNOFF-TO-RAINFALL RATIO

TABLE IV-7

ANNUAL URBAN RUNOFF INFORMATION FOR
PRESENTATION AREAS

<u>PRESENTATION AREA</u>	<u>URBAN AREA (km²)</u>	<u>ESTIMATED FRACTION IMPERVIOUS¹</u>	<u>RAINFALL TO RUNOFF RATIO, R_v</u>	<u>ESTIMATED RUNOFF² (m³/yr)</u>
A	205	.53	.38	66 × 10 ⁶
B	101	.46	.34	29 × 10 ⁶
C	204	.43	.33	57 × 10 ⁶
D	146	.43	.33	41 × 10 ⁶
E	122	.52	.37	38 × 10 ⁶
F	601	.46	.34	174 × 10 ⁶
G	<u>606</u>	<u>.51</u>	<u>.36</u>	<u>183 × 10⁶</u>
ALL	1985	.50	.35	588 × 10 ⁶

¹Urban area only.²Based on 85 cm/yr rainfall.

$$\text{Estimated Runoff (m}^3\text{/yr)} = \text{Urban Area (km}^2\text{)} \times \text{Rainfall Volume (cm/yr)} \\ \times \text{Runoff-to-Rainfall Ratio} \times \text{Unit Conversion}$$

$$= A_{\text{urban}} \times V \times R_v \times 10^4$$

upon an estimation of the concentration of pollutants in the stormwater. The estimate of concentration, combined with the estimate of runoff volume derived from the procedures developed in the previous section, provides sufficient information to calculate approximate urban stormwater loads.

Pollutant values currently reported in national literature indicate a large variation in pollutant concentrations, both in data from different geographical areas and from multiple storms at a single location. Much of this variation in measured concentrations is due to the antecedent conditions and storm characteristics for each event; these would include time since last rainfall, volume of runoff, street sweeping practices, and other factors. Thus, for a reasonable assessment of stormwater loadings from a given area, a set of values should be developed for the study area itself or chosen from areas as similar to the study area as possible. In the selection of average stormwater pollutant values for this initial assessment, both national and local sampling data were reviewed. National data are available from numerous cities and have been summarized in many federal and state publications. (2,8,9) Local data are available from several urban storm surveys conducted in the Dallas/Fort Worth area by the Texas Water Quality Board, the Trinity River Authority, and the city of Dallas. Table IV-8 presents the range of national and local data as well as the values chosen for the present

TABLE IV-8

AVERAGE CONCENTRATIONS IN URBAN RUNOFF

PARAMETER	COMMON RANGE IN URBAN AREAS* (mg/l)	NATIONAL AVERAGE* (mg/l)	RANGE OF AVERAGE CONCENTRATIONS IN LOCAL STORMWATER (mg/l)	VALUES CHOSEN FOR INITIAL ESTIMATE (mg/l)
BOD ₅	2-50	27	1-15	10
N	1.0-4.0	2.3	0.7-3.5	2.5
P	0.1-1.0	0.5	.07-1.2	0.5
TSS	50-1200	608	27-897	608

* Reference 8.

assessment. The local and national data are in close agreement for average nitrogen, phosphorus, and total suspended solids values. However, local BOD₅ values appear to be noticeably less than the national average and thus a value of 10 mg/l was chosen rather than the national average of 27 mg/l.

All of the concentration values chosen are to be considered as interim selections. Local stormwater sampling data are quite limited. Refined evaluations of appropriate local concentrations will be possible following the special sampling surveys scheduled by NCTCOG during 1977 and 1978.

The concentration values listed in Table IV-8 were applied to the runoff volumes previously presented in Table IV-7 to obtain the estimated annual stormwater loads for the urban portions of the presentation areas. These pollutant loads are shown in Table IV-9.

Figure IV-5 has been provided to facilitate the calculation of loads from the presentation areas if concentrations other than the present values are chosen. This figure allows the calculation of a pollutant load from each presentation area for any pollutant concentration in the range of zero to 50 mg/l and provides an indication of the change in the pollutant load estimates which would result from alternate choices of concentration values.

D. Storm Event Variations.

An important aspect of the evaluation of the effects of stormwater runoff is the determination of the frequency

TABLE IV-9
AVERAGE ANNUAL URBAN STORMWATER LOADS*

PRESENTATION AREA	BOD ₅ (kg/yr)	TOTAL N (kg/yr)	TOTAL P (kg/yr)	SEDIMENT (kg/yr)
A	660,000	165,000	33,000	40×10^6
B	290,000	70,000	15,000	17×10^6
C	570,000	145,000	29,000	35×10^6
D	410,000	100,000	21,000	25×10^6
E	380,000	95,000	19,000	23×10^6
F	1,740,000	440,000	87,000	106×10^6
G	1,830,000	460,000	91,000	111×10^6
Total	5,880,000 kg/yr	1,475,000 kg/yr	295,000 kg/yr	357×10^6 kg/yr
Average Loading Rate	$2,960 \text{ kg/km}^2\text{-yr}$	$740 \text{ kg/km}^2\text{-yr}$	$150 \text{ kg/km}^2\text{-yr}$	$180,000 \text{ kg/km}^2\text{-yr}$

* Based on the following estimates of average storm concentrations:

BOD₅ = 10 mg/l
N = 2.5 mg/l

P = 0.5 mg/l
TSS = 608 mg/l

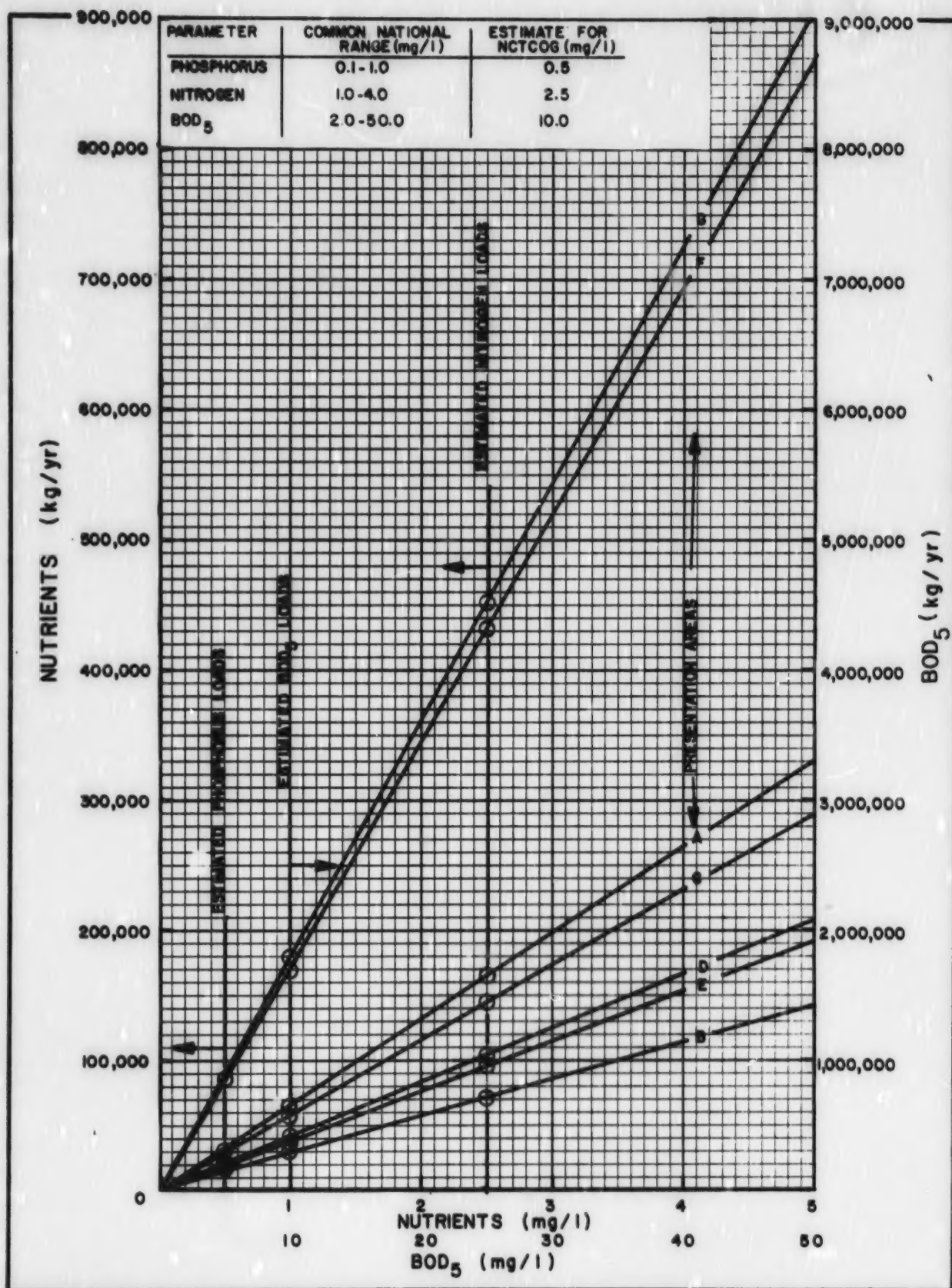


FIGURE IV-5
ANNUAL URBAN STORMWATER LOADS
FOR PRESENTATION AREAS

with which pollutant loads of various magnitudes can be expected to occur. Considerable aid in this type of analysis is provided by a statistical approach--the Statistical Method--which has been designed specifically for rainfall related phenomena. (2,8)

1. Methodology. The Statistical Method begins with an analysis of rainfall, the basic driving force in the generation of stormwater loads. Rain gage data must be analyzed to provide a statistical summary of the rainfall process. This type of analysis has been presented earlier in this chapter. Once the mean, $\bar{x}$, the standard deviation, σ , and the coefficient of variation, v , of the rainfall characteristics have been determined, a probability function is then developed. This is done through the common assumption that the rainfall parameters--storm intensity, i ; duration, d ; volume, v , and time between storms, δ --behave according to a form of the gamma distribution function. The gamma distribution function is one of the basic probability distributions commonly discussed in statistics texts. (36,37) The use of this probability function permits the calculation of the frequency of occurrence of the various stormwater phenomena.

The appropriateness of using the gamma distribution to evaluate rainfall phenomena in the Planning Area can be evaluated by comparing the curve calculated for this distribution with the data available from the Dallas rain gage at Love Field. The Dallas data in Table IV-2 indicate that

the mean volume per storm is 0.99 centimeters. The coefficient of variation is 1.6, which is calculated as follows:

$$v = \frac{\sigma}{\bar{x}} = \frac{1.58}{0.99} = 1.6$$

The gamma probability distribution for these parameters is shown on Figure IV-6. The figure also shows the actual distribution of rainfall volumes at the Dallas gage; these values have been presented previously in Table IV-4. The calculated values and observed values show excellent agreement. Thus, the use of the gamma distribution appears to be an appropriate approach for the analysis of the rainfall-related phenomena in the Planning Area.

The gamma distribution may also be used to estimate the frequency of occurrence of pollutant loads. The appropriate curve for these estimates is shown on Figure IV-7 along with the curve for the rainfall analysis. As will be shown, these curves form the basis of the remaining calculations in this chapter.

2. Mean Storm Loads. The mean pollutant load for urban stormwater runoff in each of the presentation areas can be calculated by dividing the average annual stormwater pollutant loads by the average number of storms per year. The average annual stormwater loads have been shown previously in Table IV-9 and the average number of storms for the Planning Area has previously been shown to be 86 storms per

DALLAS RAIN GAGE
NWS No. 412244
PERIOD OF RECORD 1949 - 1972

● OBSERVED
— THEORETICAL (GAMMA DISTRIBUTION)
MEAN = $\bar{X}$ = 0.99 cm
COEFFICIENT OF VARIATION = V = 1.60

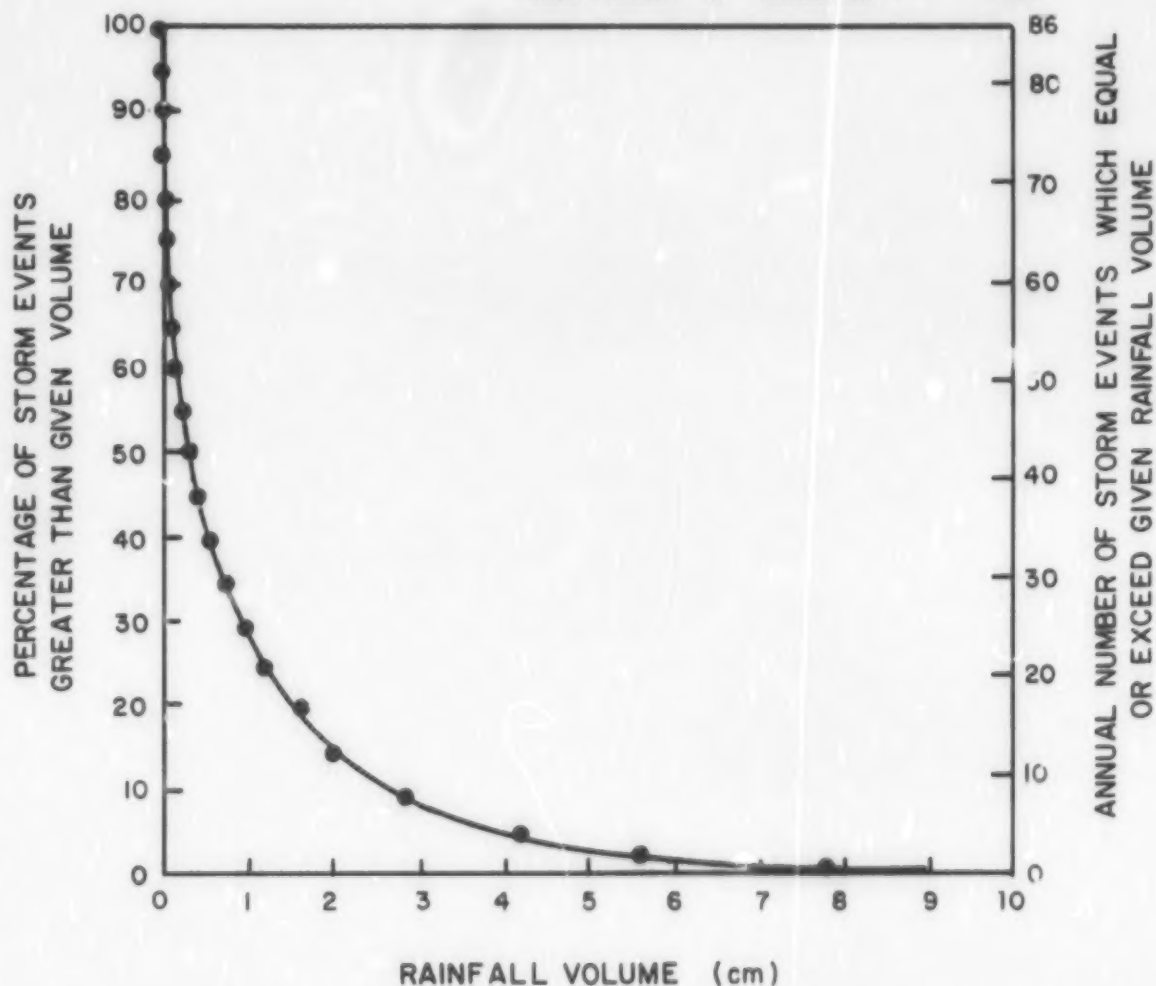


FIGURE IV - 6
COMPARISON BETWEEN THEORETICAL AND
OBSERVED RAINFALL CHARACTERISTICS
DALLAS LOVE FIELD RAIN GAGE

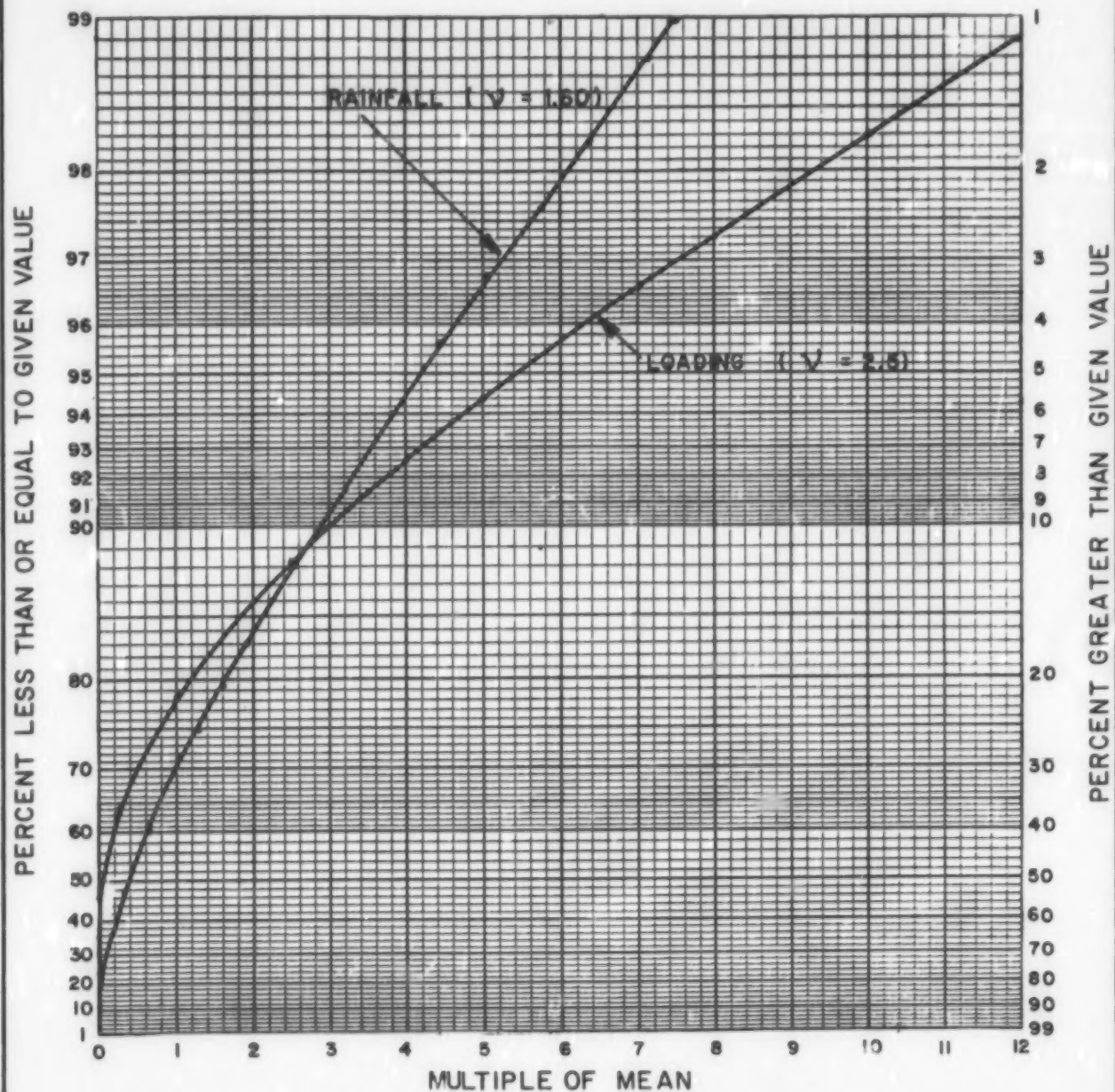


FIGURE IV-7
PLANNING AREA GENERALIZED URBAN
RAINFALL AND LOADING CURVES

year. Thus, the mean urban storm loads for BOD₅, nitrogen, phosphorus, and total suspended solids were calculated and their values are shown in Table IV-10.

3. Frequency of Occurrence of Storm Loads. By combining the mean storm loads with the distribution curves shown previously in Figure IV-7, the expected frequency of occurrence of various pollutant loads can be calculated for storms in the Planning Area. The resulting values for each of the presentation areas are shown in Tables IV-11 through IV-17. These tables provide estimates of how many times a given pollutant load from a storm event can be expected during the year or during the four month summer period of June, July, August, and September. This summer period was highlighted because receiving waters such as the Trinity River are generally most sensitive to pollution loads in the summer.

To illustrate the meaning of these calculations, Table IV-15 for the Presentation Area E (East Fork below Lakes) will be discussed. The approximate mean urban storm load for BOD₅ in this presentation area is 4400 kilograms. Because of the large number of small storms in the area, most of the storms cause smaller pollutant loads than this average load. The table shows that 78.5% of the storms can be expected to produce a BOD₅ load less than 4400 kilograms and 21.5% of the storms can be expected to produce a BOD₅ load exceeding 4400 kilograms. As shown on the table, this means that, out of the 86 storms a year,

TABLE IV-10
MEAN URBAN STORM LOADS FOR PRESENTATION AREAS*

<u>PRESENTATION AREA</u>	<u>BOD₅ (kg)</u>	<u>N (kg)</u>	<u>P (kg)</u>	<u>TSS (kg)</u>
A	7,700	1,900	380	470,000
B	3,400	840	170	210,000
C	6,600	1,700	330	400,000
D	4,800	1,200	240	290,000
E	4,400	1,100	220	270,000
F	20,000	5,100	1,000	1,200,000
G	21,000	5,300	1,100	1,300,000

* Mean Urban Storm Load

$$= \frac{\text{Estimated Annual Pollution Load From Urban Storm Runoff}}{\text{Number of Storms Per Year}}$$

TABLE IV-11
EXPECTED FREQUENCY OF URBAN STORM LOADS OF PRESENTATION AREA A (WEST FORK LAKES)

BOD5 (kg)	TOTAL N (kg)	TOTAL P (kg)	SEDIMENT (kg)	RATIO OF GIVEN LOAD TO AVERAGE		PERCENT OF STORMS LESS THAN GIVEN VALUE		PERCENT OF STORMS GREATER THAN GIVEN VALUE		EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER YEAR ¹ PER SUMMER ²	
				LOAD	VALUE	VALUE	VALUE				
539	133	27	32,900	0.07	50.0	50.0	43.0	43.0	13.0		
1,925	475	95	117,500	0.25	63.9	36.1	31.0	31.0	9.4		
3,850	950	190	235,000	0.50	71.0	29.0	24.9	24.9	7.5		
7,700	1,900	380	470,000	1.00	78.5	21.5	18.5	18.5	5.6		
15,400	3,800	760	940,000	2.00	86.0	14.0	12.0	12.0	3.6		
23,100	5,700	1,140	1,410,000	3.00	90.0	10.0	8.6	8.6	2.6		
30,800	7,600	1,520	1,880,000	4.00	92.6	7.4	6.4	6.4	1.9		
38,500	9,500	1,900	2,350,000	5.00	94.4	5.6	4.8	4.8	1.5		
53,900	13,300	2,660	3,290,000	7.00	96.6	3.4	2.9	2.9	0.88	(7 summers out of 8)	
77,000	19,000	3,800	4,700,000	10.00	98.3	1.7	1.5	1.5	0.44	(4 summers out of 9)	
92,400	22,800	4,560	5,640,000	12.00	98.9	1.1	0.95	0.95	0.29	(3 summers out of 10)	
96,250	23,750	4,750	5,875,000	12.50	99.0	1.0	0.86	0.86	0.26	(1 summer out of 4)	
								(6 years out of 7)			

¹ Based upon 86 storms per year.

² Based upon 26 storms occurring from June through September.

TABLE IV-12
EXPECTED FREQUENCY OF URBAN STORM LOADS OF PRESENTATION AREA B (ELM FORK LAKES)

BOD ₅ (kg)	TOTAL N (kg)	TOTAL P (kg)	SEDIMENT (kg)	RATIO OF GIVEN LOAD TO AVERAGE LOAD	PERCENT OF STORMS LESS THAN GIVEN VALUE	PERCENT OF STORMS GREATER THAN GIVEN VALUE	EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER YEAR ¹	EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER SUMMER ²
238	59	12	14,700	0.07	50.0	50.0	43.0	13.0
850	210	43	52,500	0.25	63.9	36.1	21.0	9.4
1,700	420	85	105,000	0.50	71.0	29.0	24.9	7.5
3,400	840	170	210,000	1.00	78.5	21.5	18.5	5.6
6,800	1,680	340	420,000	2.00	86.0	14.0	12.0	3.6
10,200	2,520	510	630,000	3.00	90.0	10.0	8.6	2.6
13,600	3,360	680	840,000	4.00	92.6	7.4	6.4	1.9
17,000	4,200	850	1,050,000	5.00	94.4	5.6	4.8	1.5
23,800	5,880	1,190	1,470,000	7.00	96.6	3.4	2.9	0.88 (7 summers out of 8)
34,000	8,400	1,700	2,100,000	10.00	98.3	1.7	1.5	0.44 (4 summers out of 9)
40,800	10,080	2,040	2,520,000	12.00	98.9	1.1	0.95	0.29 (3 summers out of 10)
42,500	10,500	2,125	2,625,000	12.50	99.0	1.0	0.86 (6 years out of 7)	0.26 (1 summer out of 4)

¹Based upon 86 storms per year.

²Based upon 26 storms occurring from June through September.

TABLE IV-13
EXPECTED FREQUENCY OF URBAN STORM LOADS OF PRESENTATION AREA C (ELM FORK BELOW LAKES)

BOD ₅ (kg)	TOTAL N (kg)	TOTAL P (kg)	SEDIMENT (kg)	RATIO OF GIVEN LOAD TO AVERAGE LOAD	PERCENT OF STORMS LESS THAN GIVEN VALUE		PERCENT OF STORMS GREATER THAN GIVEN VALUE		EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER YEAR ¹ PER SUMMER ²	
					VALUE		VALUE		PER YEAR ¹ PER SUMMER ²	
462	119	23	28,000	0.07	50.0	50.0	50.0	43.0	13.0	
1,650	425	83	100,000	0.25	63.9	36.1	36.1	31.0	9.4	
3,300	850	165	200,000	0.50	71.0	29.0	29.0	24.9	7.5	
6,600	1,700	330	400,000	1.00	78.5	21.5	21.5	18.5	5.6	
13,200	3,400	660	800,000	2.00	86.0	14.0	14.0	12.0	3.6	
19,800	5,100	990	1,200,000	3.00	90.0	10.0	10.0	8.6	2.6	
26,400	6,800	1,320	1,600,000	4.00	92.6	7.4	7.4	6.4	1.9	
33,000	8,500	1,650	2,000,000	5.00	94.4	5.6	5.6	4.8	1.5	
46,200	11,900	2,310	2,800,000	7.00	96.6	3.4	3.4	2.9	0.88	(7 summers out of 8)
66,000	17,000	3,300	4,000,000	10.00	98.3	1.7	1.7	1.5	0.44	(4 summers out of 9)
79,200	20,400	3,960	4,800,000	12.00	98.9	1.1	1.1	0.95	0.29	(3 summers out of 10)
82,500	21,250	4,125	5,000,000	12.50	99.0	1.0	1.0	0.86	0.25	(1 summer out of 4)

¹Based upon 86 storms per year.

²Based upon 26 storms occurring from June through September.

TABLE IV-14
EXPECTED FREQUENCY OF URBAN STORM LOADS OF PRESENTATION AREA D (EAST FORK LAKES)

BOO'S (kg)	TOTAL H (kg)	TOTAL P (kg)	SEDIMENT (kg)	RATIO OF GIVEN LOAD TO AVERAGE LOAD	PERCENT OF STORMS LESS THAN GIVEN VALUE	PERCENT OF STORMS GREATER THAN GIVEN VALUE	EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER YEAR ¹	EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER SUMMER ²
336	84	17	20,300	0.07	50.0	50.0	43.0	13.0
1,200	300	60	72,500	0.25	63.9	36.1	31.0	9.4
2,400	600	120	145,000	0.50	71.0	29.0	24.9	7.5
4,800	1,200	240	290,000	1.00	78.5	21.5	18.5	5.6
9,600	2,400	480	580,000	2.00	86.0	14.0	12.0	3.6
14,400	3,600	720	870,000	3.00	90.0	10.0	8.6	2.6
19,200	4,800	960	1,160,000	4.00	92.6	7.4	6.4	1.9
24,000	6,000	1,200	1,450,000	5.00	94.4	5.6	4.8	1.5
22,600	8,400	1,680	2,030,000	7.00	96.6	3.4	2.9	0.88 (7 summers out of 8)
48,000	12,000	2,400	2,900,000	10.00	98.3	1.7	1.5	0.44 (4 summers out of 9)
57,600	14,400	2,880	3,480,000	12.00	98.9	1.1	0.95	0.39 (3 summers out of 10)
60,000	15,000	3,000	3,625,000	12.50	99.0	1.0	0.86 (6 years out of 7)	0.26 (1 summer out of 4)

¹Based upon 86 storms per year.

²Based upon 26 storms occurring from June through September.

TABLE IV-15
EXPECTED FREQUENCY OF URBAN STORM LOADS OF PRESENTATION AREA E (EAST FORK BELOW LAKES)

LOAD (kg)	TOTAL N (kg)	TOTAL P (kg)	SEDIMENT (kg)	RATIO OF GIVEN LOAD TO AVERAGE LOAD	PERCENT OF STORMS LESS THAN GIVEN VALUE	PERCENT OF STORMS GREATER THAN GIVEN VALUE	EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER YEAR ¹	PER SUMMER ²
308	77	15	18,900	0.07	50.0	50.0	43.0	13.0
440	110	22	27,000	0.10	54.0	46.0	39.6	12.0
850	209	42	51,300	0.19	60.8	39.2	33.7	10.2
1,100	275	55	67,500	0.25	63.9	36.1	31.0	9.4
2,200	550	110	135,000	0.50	72.0	29.0	24.9	7.5
4,400	1,100	220	270,000	1.00	78.5	21.5	18.5	5.6
8,800	2,200	440	540,000	2.00	86.0	14.0	12.0	3.6
13,200	3,300	660	810,000	3.00	90.0	10.0	8.6	2.6
17,600	4,400	880	1,080,000	4.00	92.6	7.4	6.4	1.9
22,000	5,500	1,100	1,350,000	5.00	94.4	5.6	4.8	1.5
30,800	7,700	1,540	1,890,000	7.00	96.6	3.4	2.9	0.89 (7 summers out of 8)
44,000	11,000	2,200	2,700,000	10.00	98.3	1.7	1.5	0.44 (4 summers out of 9)
52,800	13,200	2,640	3,240,000	12.00	98.9	1.1	0.95	0.29 (3 summers out of 10)
55,000	13,750	2,750	3,375,000	12.50	99.0	1.0	0.86 (6 years out of 7)	0.26 (1 summer out of 4)

¹Based upon 86 storms per year.

²Based upon 26 storms occurring from June through September.

TABLE IV-16
EXPECTED FREQUENCY OF URBAN STORM LOADS OF PRESENTATION AREA F (WEST FORK BELOW LAKES)

BCD5 (kg)	TOTAL N (kg)	TOTAL P (kg)	SEDIMENT (kg)	RATIO OF GIVEN LOAD TO AVERAGE LOAD	PERCENT OF STORMS LESS THAN GIVEN VALUE	PERCENT OF STORMS GREATER THAN GIVEN VALUE	EXPECTED NUMBER OF STORMS GREATER THAN GIVEN LOAD PER YEAR ¹	PER SUMMER ²
440	102	20	24,000	0.02	38.0	62.0	53.3	16.1
850	204	40	48,000	0.04	45.0	55.0	47.3	14.3
1,400	357	70	84,000	0.07	50.0	50.0	43.0	13.0
5,000	1,275	250	300,000	0.25	63.9	36.1	31.0	9.4
10,000	2,550	500	600,000	0.50	71.0	29.0	24.9	7.5
20,000	5,100	1,000	1,200,000	1.00	78.5	21.5	18.5	5.6
40,000	10,200	2,000	2,400,000	2.00	86.0	14.0	12.0	3.6
60,000	15,300	3,000	3,600,000	3.00	90.0	10.0	8.6	2.6
80,000	20,400	4,000	4,800,000	4.00	92.6	7.4	6.4	1.9
100,000	25,500	5,000	6,000,000	5.00	94.4	5.6	4.8	1.5
140,000	35,700	7,000	8,400,000	7.00	96.6	3.4	2.9	0.88 (7 summers out of 8)
200,000	51,000	10,000	12,000,000	10.00	98.3	1.7	1.5	0.44 (4 summers out of 9)
240,000	61,200	12,000	14,400,000	12.00	98.9	1.1	0.95	0.29 (3 summers out of 10)
250,000	63,750	12,500	15,000,000	12.50	99.0	1.0	0.86 (6 years out of 7)	0.26 (1 summer out of 4)

¹Based upon 86 storms per year.

²Based upon 26 storms occurring from June through September.

TABLE IV-17

[illegible]

! - - - - - 16 stories per year.

¹Based upon 86 storms per year.
²Based upon 26 storms occurring from June through September.

approximately 18 storms will have a BOD₅ load greater than 4400 kilograms and, out of the 26 summer storms, approximately 5 will have a BOD₅ load greater than 4400 kilograms. To investigate a more extreme event, the table demonstrates that once a year a storm can be expected to produce a BOD₅ load of approximately 52,800 kilograms, which represents 12 times the mean load. The table also shows that 3 times in 10 years this load of 52,800 kilograms can be expected in the summer period.

A word of caution is appropriate at this point regarding Figure IV-7, which was used to generate the frequency of occurrence of various pollutant loads. In the use of Figure IV-7, the magnitudes of pollution loads are assumed to be independent of the magnitudes of the rainfall volumes. A medium level rainfall does not necessarily correspond to a medium level pollution-load and a large rainfall does not necessarily correspond to a large pollution load. Thus, Figure IV-7 cannot be interpreted to mean that a 96% level of rainfall, for example, produces a 96% level of pollution load. This independent behavior is reasonable because of the many random situations which can occur simultaneously. For example, a medium level rainfall could produce an extremely large pollution load if this rainfall occurred after a long dry period when large amounts of pollutants accumulated in the urban area. Similarly, a large volume of rainfall could produce a relatively small amount of

pollution if this storm occurred shortly after a storm which had washed off the area.

4. Comparison with Point Sources. These calculations provide a basis for comparing urban stormwater loads with point source loads. Since essentially all these storm loads occur in less than a 24-hour period, they may be expressed as a daily loading rate which can be compared directly with the daily loading rates from waste treatment plants in the same area. For example, Figures IV-8 through IV-10 compare the stormwater BOD₅ loading rates with the point source loading rates for the three conditions defined earlier. This comparison can be summarized as follows for Presentation Area E:

- 1) For Condition 1 (1975-1976 conditions), approximately 14% of the storms would result in a larger urban runoff load of BOD₅ than daily point source loads;
- 2) For Condition 2 (several major plants with a 10 mg/l BOD₅ effluent), approximately 39% of the storms would result in a larger urban runoff load than daily point source loads; and
- 3) For Condition 3 (several major plants with a 5 mg/l BOD₅ effluent), approximately 46% of the storms would result in a larger urban runoff load than a daily point source load.

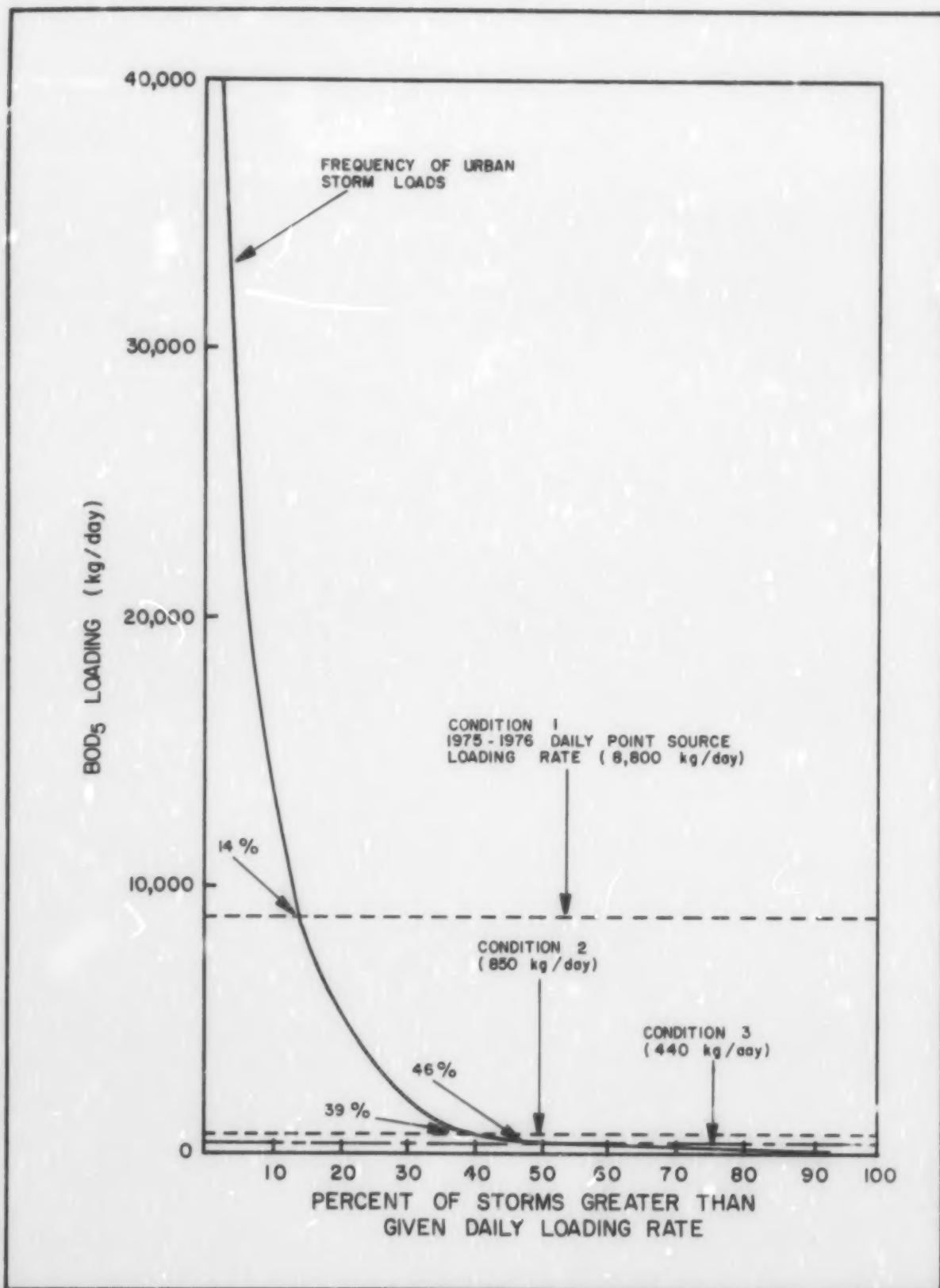


FIGURE IV-8
DAILY LOAD COMPARISONS
PRESENTATION AREA E

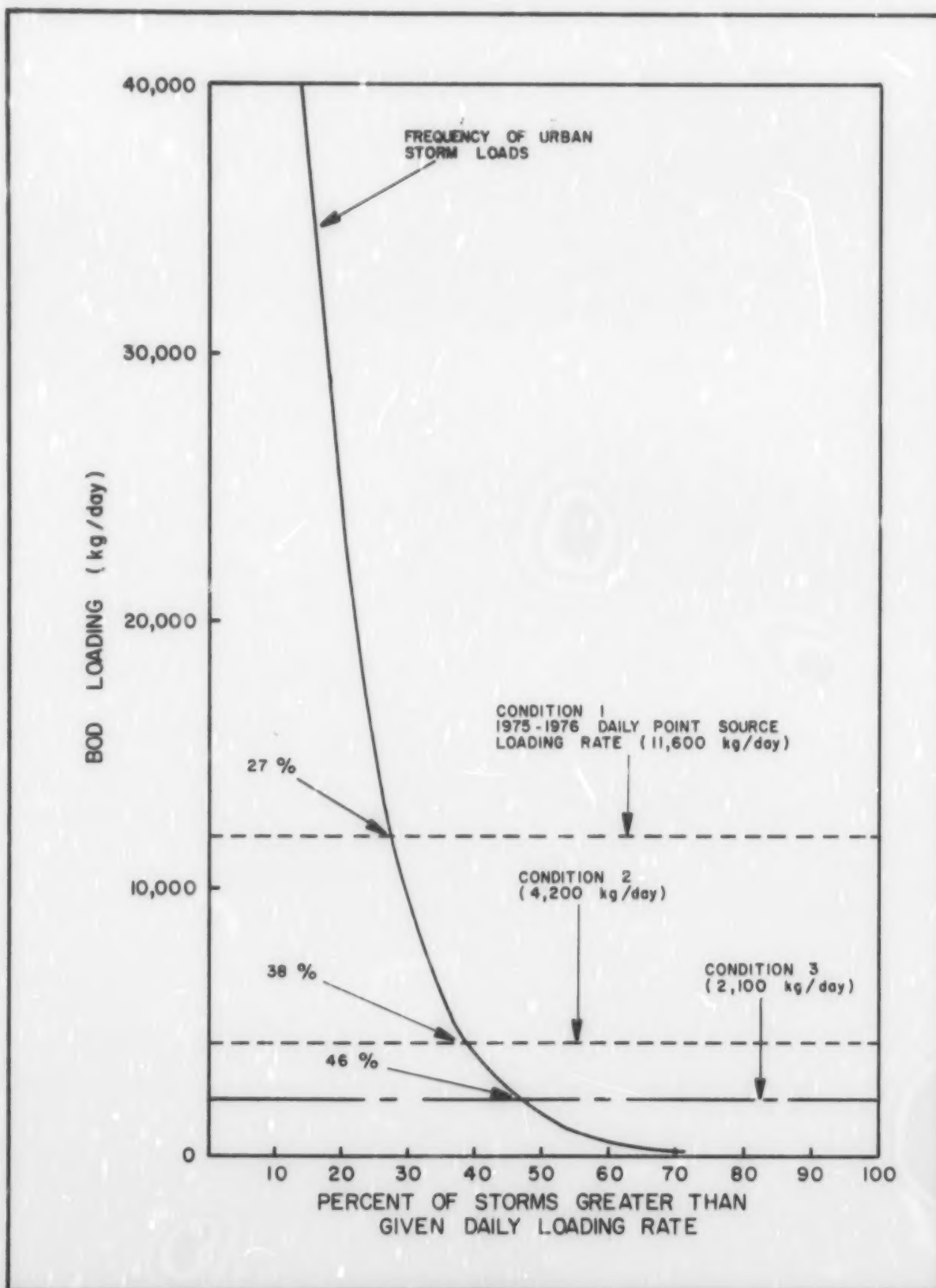


FIGURE IV-9
DAILY LOAD COMPARISONS
PRESENTATION AREA F

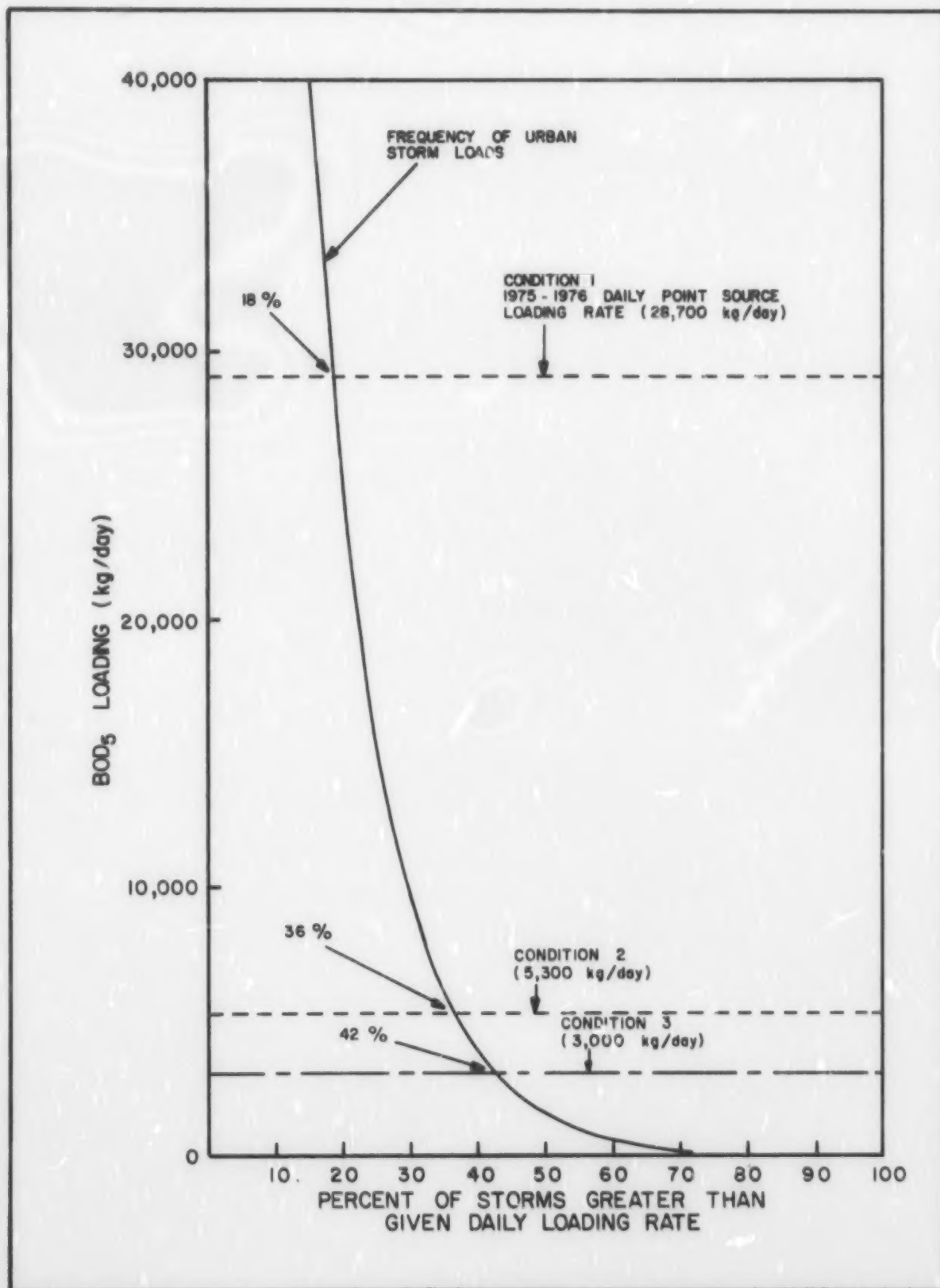


FIGURE IV-10
DAILY LOAD COMPARISONS
PRESENTATION AREA G

This analysis indicates that for Conditions 2 and 3, a large number of the urban runoff loads of BOD₅ would exceed the daily point source loads in the same area. Similar results are shown for Presentation Areas F and G.

CHAPTER V
RURAL RUNOFF

CHAPTER V

RURAL RUNOFF

As shown previously in Chapter II, over 72 percent of the Planning Area has the rural land use designations of "grassland" or "cropland." Unfortunately, available literature estimates of nonpoint pollution from rural areas vary greatly. Thus, reliable estimates for a particular study area should be based upon as much local data as possible. The present chapter provides a brief summary of national and local data for BOD₅, nitrogen, phosphorus, and sediment values for rural runoff as well as initial estimates of the contributions of these pollutants from rural nonpoint sources in the Planning Area.

A. BOD₅, Nitrogen, and Phosphorus.

The results of several inventories of studies involving nonpoint source pollutant loading rates are shown in Table V-1. This table indicates that a wide range of values is possible for various land uses but that urban and agricultural uses appear to produce approximately two to four times more of these pollutants per unit area than forested or grassland areas.

Data for many scattered water quality samples are available for rural areas in the upper Trinity Basin.⁽¹⁰⁾ One recent set of EPA sampling data⁽¹¹⁾ permits a preliminary estimate of overall nonpoint nutrient loadings to three local lakes: Lake Lewisville, Lake Lavon, and Lake Eagle

TABLE V-1

SUMMARY OF NATIONAL NONPOINT SOURCE LOADING RATES

GEOGRAPHICAL LOCATION	LAND USE	BOD ₅ (kg/km ² -yr)		TOTAL N (kg/km ² -yr)		TOTAL P (kg/km ² -yr)	
		Average	Range	Average	Range	Average	Range
MULTI-STUDY AVERAGES ¹	Forest	510	400-700	260	83-1020	16	.6-89
	Pasture	1100	600-1700	510	250-850	32	25-64
	Urban	4500	1300-8200	510	210-1800	83	25-500
	Agriculture	2600	400-3600	960	120-3700	64	3-250
EASTERN U.S. ²	Forest			440	--	8	--
	Mostly Forest			450	--	17	--
	Mixed			550	--	18	--
	Mostly Urban			790	--	30	--
	Mostly Agriculture , Agriculture			630	--	23	--
				980	--	31	--

¹ Reference 8.² Reference 12.

Mountain. The nutrient loading values for these lakes as well as several of their tributaries is shown in Table V-2. All of these areas represent mixed land uses, including grassland, cropland, and a small amount of urban land. The lowest values for nonpoint loadings shown in the table are $70 \text{ kg/km}^2\text{-yr}$ for nitrogen and $7 \text{ kg/km}^2\text{-yr}$ for phosphorus. These values can be considered to be close to the background values which would exist in the area in the absence of human activities.

B. Sediment.

On a national scale, estimates of sediment loading rates to streams vary even more than estimates of BOD_5 and nutrients. Several methods can be applied to estimate sediment loading rates including calculations based on runoff from small plots of land, measurements of sediment build-up in reservoirs, and samples of total suspended solids (TSS) in streams. Of these methods TSS measurements in streams tend to give lower estimates of sediment movement than other methods. This is possibly due to inadequate estimates of the amount of bed load being moved past a particular point or insufficient number of samples being taken during high flow periods when much of the sediment is being transported. Some amount of error is also possible in reservoir sedimentation studies because of the difficulty in estimating the density of the soil which is settling out in various portions of the water body.

TABLE V-2

NONPOINT SOURCE NUTRIENT LOADING RATES TO LOCAL LAKES*

<u>LAKE LEWISVILLE</u>		
LOCATION	TOTAL N (kg/km ² -yr)	TOTAL P (kg/km ² -yr)
Elm Fork	290	35
Clear Creek	80	7
Isle DuBois Creek	220	23
Little Elm Creek	360	45
Drainage Basin Average	180	19
<u>LAKE LAVON</u>		
LOCATION	TOTAL N (kg/km ² -yr)	TOTAL P (kg/km ² -yr)
East Fork	510	54
White Rock Creek	580	7
Wilson Creek	450	37
Sister Grove Creek	300	18
Pilot Grove Creek	270	21
Drainage Basin Average	390	31
<u>LAKE EAGLE MOUNTAIN</u>		
LOCATION	TOTAL N (kg/km ² -yr)	TOTAL P (kg/km ² -yr)
West Fork	70	10
Ash Creek	110	19
Walnut Creek	150	11
Drainage Basin Average	80	11

*Reference 11.

Table V-3 is included to provide an overview of sediment loading rates which have been observed throughout the country. The EPA assessment on this table shows that, on the average, cropland tends to produce approximately twenty times as much sediment as grassland.

An extensive amount of sediment data is available for the upper Trinity Basin. Table V-4 provides summaries of three types of studies in the area; local lake sedimentation studies, local county-wide sediment loading estimates, and Trinity River suspended sediment studies. Land resource areas, soil types, and agricultural activities appear to play a significant role in determining the amount of sediment generated in various parts of the region. The lake study summaries provide information on four major lakes in the Planning Area. Lake Lavon, whose drainage area is located entirely in the Blackland Prairie resource area, has a significantly higher sedimentation rate than the other three lakes, whose drainage areas include portions of other resource areas such as East Cross Timbers, Grand Prairie, West Cross Timbers, and Central Rolling Red Prairies. The summaries of county sediment loading rates also demonstrate the range of values possible in the local area as a result of different combinations of soil groups and land uses.

C. Rural Loading Rates For The Planning Area.

The pollutant loading rates chosen for rural areas in the Planning Area are shown in Table V-5. On this table,

TABLE V-3
SUMMARY OF NATIONAL SEDIMENT LOADING RATES

STUDY	LAND USE	SEDIMENT EROSION RATE (kg/km ² -yr)		RANGE (kg/km ² -yr)
National Assessment, EPA ¹	Forest	8,500		
	Grassland	85,000		
	Abandoned Surface Mines	850,000		
	Cropland	1,700,000		
	Harvested Forest	4,300,000		
	Active Surface Mines	17,000,000		
	Construction	17,000,000		
Multi-Study Averages ²	Forest	26,000	TSS (kg/km ² -yr)	5,000-40,000
	Pasture	43,000		1,000-84,000
	Agriculture	160,000		29,000-420,000
	Urban	220,000		20,000-480,000

¹References 13, 14.

²Reference 8.

TABLE V-4
LOCAL SEDIMENT LOADING RATES

<u>Local Lake Studies¹</u>		
Lake	Period of Record	Sediment Loading Rate (kg/km ² -yr)
White Rock Lake	1910-1970	305,000
Grapevine Lake	1952-1966	317,000
Lewisville Lake	1954-1965	478,000
Lavon Lake	1953-1965	821,000

<u>Local County Inventories²</u>	
County	Sediment Loading Rate (kg/km ² -yr)
Collin	1,321,000
Cooke	572,000
Dallas	896,000
Denton	957,000
Ellis	1,395,000
Grayson	1,205,000
Jack	198,000
Johnson	968,000
Kaufman	554,000
Montague	215,000
Parker	143,000
Rockwall	994,000
Tarrant	585,000
Wise	148,000

<u>Suspended Sediment Studies in Trinity Basin³</u>			
Stream	Period of Record	TSS (kg/km ² -yr)	Range (kg/km ² -yr)
Little Elm Creek	1964-1968	204,000	38,000-303,000
Trinity River at Rosser	1938-1940, 1953-1971	42,000	6,000-206,000
Chambers Creek	1963-1971	114,000	14,000-248,000
Trinity River at Crockett	1968-1971	36,000	13,000-51,000
Long King Creek	1963-1971	110,000	8,000-328,000
Trinity River at Romayer	1936-1971	86,000	1,000-276,000

¹References 15, 16, 17, 18

²Reference 19.

³Reference 20.

TABLE V-5

ESTIMATED RURAL LOADING RATES FOR THE PLANNING AREA

a) PRESENTATION AREAS A,B,C,F

<u>Parameter</u>	<u>Grassland (kg/km²-yr)</u>	<u>Cropland (kg/km²-yr)</u>
BOD ₅	1,100	2,600
N	100	300
P	11	33
Sediment	55,000	1,100,000

b) PRESENTATION AREAS D,E,G

<u>Parameter</u>	<u>Grassland (kg/km²-yr)</u>	<u>Cropland (kg/km²-yr)</u>
BOD ₅	1,100	2,600
N	193	579
P	15	45
Sediment	77,000	1,540,000

the Presentation Areas are divided into two groups to reflect the differences which apparently exist in drainage from Blackland Prairie areas and drainage from other resource areas. Presentation Areas D, E, and G are located within the Blackland Prairie resource area and thus have somewhat higher loading rates; these higher loading rates are apparent from the lake nutrient studies summarized previously in Table V-2 and the lake sediment studies summarized previously in Table V-4. The following procedures were used to determine the rural pollutant loading rates displayed in Table V-5 for BOD₅, nitrogen, phosphorus, and sediment:

1. BOD₅. Since no data were readily available for the local area from which a distinction could be made for grassland versus cropland BOD₅ loading rates, the national average values for BOD₅ previously shown in Table V-1 were used. Ongoing sampling programs in the Planning Area may permit a refinement of these values before the end of this study.

2. Nutrients. The nutrient loading rates from cropland areas were assumed to be three times the nutrient loading rates from grassland areas. This assumption appears to be in reasonable agreement with both national assessments and available local data. Calculations of the actual loading rates were then based upon the lake summaries shown previously in Table V-2. Lake Lavon's nitrogen and

phosphorus loading rates were assumed to typify drainage from Blackland Prairie areas and Lake Lewisville's nitrogen and phosphorus loading rates were assumed to typify drainage primarily from other resource areas.

3. Sediment. Sediment loading rates from cropland areas were assumed to be twenty times the loading rates from grassland areas. This assumption appears to be in reasonable agreement with both national assessments and available calculations by the Soil Conservation Service in applications of the Universal Soil Loss Equation to local areas.⁽²¹⁾ Calculations of the actual sediment loading rates were then based upon the lake summaries shown previously in Table V-4 for Lake Lavon and Lake Lewisville.

D. Background Loading Rates.

From the calculations presented thus far, estimates can be made of the background conditions which would exist in the study area in the absence of human activity. These values are shown on Table V-6. The estimates for nutrients were chosen from the lowest values appearing in the local lake data shown previously on Table V-2. These background loading rates for nutrients amounted to approximately seventy percent of the nutrient loading rates for grassland in Presentation Areas A, B, C, and F, as shown in Table V-5. Similarly, the background values for BOD₅ and sediment were estimated to be approximately seventy percent of the values presently being used for grassland loading rates in these areas.

TABLE V-6

ESTIMATED BACKGROUND LOADING RATES
FOR THE PLANNING AREA

Parameter	Background Loading Rate (kg/km ² -yr)
BOD ₅	800
N	70
P	7
Sediment	40,000

E. Annual Rural Loads.

The rural loading rates presented previously in Table V-5 and the land use data presented previously in Table II-4 were combined for the calculation of annual loads from the rural portions of each presentation area. The results of these calculations are shown in Table V-7.

F. Upstream Contributions.

In order to keep track of the amount of material entering the Planning Area as well as the amount of material being transferred within the area, it is necessary to determine the rate at which pollutants are crossing the boundaries of the presentation areas. A significant amount of streamflow enters Presentation Areas A, B, and D from outside the Planning Area. Preliminary estimates of land use in the upstream drainage areas as well as data from the studies of nutrients and sediments in Lake Lavon and Lake Lewisville provided sufficient information to allow initial estimates of the pollutant loads entering these three presentation areas. In addition, streamflow data and water quality sampling data collected by the U. S. Geological Survey, Texas Water Quality Board, Trinity River Authority and other agencies were evaluated to provide estimates of pollutants being transferred between presentation areas. Table V-8 summarizes these calculations. Ongoing studies, such as the present study of Lake Ray Hubbard, which is being sponsored by NCTCOG and the City of Dallas, should provide additional information for the refinement of these estimates.

TABLE V-7

AVERAGE ANNUAL RURAL LOADS FROM NONPOINT SOURCES

PRESENTATION AREA	BOD ₅ (kg/yr)		TOTAL N (kg/yr)		TOTAL P (kg/yr)		SEDIMENT (kg/yr)	
	Grassland	Cropland	Grassland	Cropland	Grassland	Cropland	Grassland	Cropland
A	1,080,000	900,000	98,000	104,000	10,800	11,500	54×10^6	382×10^6
B	890,000	590,000	81,000	68,000	8,900	7,500	45×10^6	249×10^6
C	330,000	210,000	30,000	24,000	3,300	2,600	17×10^6	87×10^6
D	650,000	1,120,000	114,000	250,000	8,900	19,400	45×10^6	665×10^6
E	360,000	410,000	63,000	91,000	4,900	7,100	25×10^6	242×10^6
F	680,000	380,000	62,000	43,000	6,800	4,800	34×10^6	159×10^6
G	850,000	1,510,000	149,000	335,000	11,600	26,100	60×10^6	892×10^6
Total	4,840,000	5,120,000	597,000	915,000	55,200	79,000	280×10^6	$2,676 \times 10^6$

TABLE V-8
LOADING RATES ENTERING BOUNDARIES OF PRESENTATION AREAS

PRESENTATION AREA	BOD ₅ (kg/yr)		N (kg/yr)		P (kg/yr)		SEDIMENT (kg/yr)	
	FROM OUTSIDE PLANNING AREA	FROM OTHER PRESENTATION AREAS	FROM OUTSIDE PLANNING AREA	FROM OTHER PRESENTATION AREAS	FROM OUTSIDE PLANNING AREA	FROM OTHER PRESENTATION AREAS	FROM OUTSIDE PLANNING AREA	FROM OTHER PRESENTATION AREAS
A	2,360,000	-	346,000	-	22,900	-	242,500,000	-
B	8,070,000	-	817,000	-	87,400	-	2,045,100,000	-
C	-	1,070,000	-	635,000	-	81,900	-	9,000,000
D	2,650,000	-	536,000	-	42,600	-	1,130,000,000	-
E	-	1,190,000	-	716,000	-	97,400	-	8,600,000
F	-	620,000	-	290,000	-	58,900	-	15,200,000
G	-	12,655,000	-	5,891,000	-	1,608,900	-	182,900,000

CHAPTER VI
COMPARISON BETWEEN SOURCES

CHAPTER VI

COMPARISON BETWEEN SOURCES

The purpose of this chapter is to provide a comparison between the major sources of the pollutants BOD₅, nitrogen, phosphorus, and sediment for the Planning Area. Five major sources will be considered: point sources, urban stormwater, grassland, cropland, and sources outside the Designated Planning Area. The comparison of sources will be accomplished by summarizing the calculations presented in previous chapters of this report and by presenting preliminary materials balances for these pollutants within the Planning Area. These values will be refined during the remaining portion of the nonpoint source study period.

Much of the material contributed from outside the Planning Area is retained in Lake Lavon, Lake Lewisville, Lake Grapevine, and Lake Worth; most of the major point sources discharge to stream sections which are downstream of these lakes. However, in this chapter, the distinction will not be made regarding whether the pollutant loads impact lakes or streams. This distinction will be discussed in Chapter VIII. In the present chapter, the primary emphases will be directed toward the relative magnitude of various types of loads to the Planning Area as a whole and the interrelationships between Presentation Areas.

A. Comparison of Sources.

The annual loads from the various sources will be presented for the following six parameters: BOD₅ Condition 1, BOD₅ Condition 2, BOD₅ Condition 3, Nitrogen, Phosphorus, and Sediment.

1. BOD₅ Condition 1. The summary of the estimated present (1975-1976) annual BOD₅ loads is shown in Table VI-1. This table demonstrates that for the entire Planning Area, approximately 39% of the BOD₅ is provided by point discharges, 12% by urban stormwater, 10% by grassland, 11% by cropland and 28% by sources outside the Planning Area.

As can be noted in the remaining analyses, significant variations do occur in the relative magnitude of the various sources within the individual Presentation Areas. For example, within Presentation Area A, grassland and cropland together produce approximately 75% of the BOD₅, whereas within Presentation Area G, they produce only 16%. In the assessment of pollution control techniques during the 1977-1978 planning cycle, NCTCOG will be examining each presentation area individually and the differences between the types of sources and types of water bodies in each area will play a key role.

2. BOD₅ Condition 2. Table VI-2 provides a summary of the estimated annual BOD₅ loads when some of the major treatment plants now under construction, as indicated in NCTCOG's 1977 Annual Water Quality Management Plan,⁽¹⁾

TABLE VI-1
ESTIMATED ANNUAL LOADS--BOD₅ CONDITION 1 (1975-1976)

PRESENTATION AREA	BOD ₅ CONDITION 1 (kg/yr)					
	POINT SOURCE	URBAN STORMWATER	GRASSLAND	CROPLAND	FROM OUTSIDE 200 PLANNING AREA	FROM OTHER PRESENTATION AREAS
A	10,000	660,000	1,080,000	900,000	2,360,000	-
B	160,000	290,000	890,000	590,000	8,070,000	-
C	260,000	570,000	330,000	210,000	-	1,070,000
D	260,000	410,000	650,000	1,120,000	2,650,000	-
E	3,200,000	380,000	360,000	410,000	-	1,190,000
F	4,210,000	1,740,000	680,000	380,000	-	620,000
G	10,470,000	1,830,000	850,000	1,510,000	-	12,655,000
TOTAL	18,570,000	5,880,000	4,840,000	5,120,000	13,080,000	
PERCENT	39%	12%	10%	11%	28%	100%
OVERALL TOTAL						= 47,490,000

TABLE VI-2

ESTIMATED ANNUAL LOADS--BOD₅ CONDITION 2

PRESENTATION AREA	BOD ₅ CONDITION 2 (kg/yr)					
	POINT SOURCE	URBAN STORMWATER	GRASSLAND	CROPLAND	FROM OUTSIDE 208 PLANNING AREA	FROM OTHER PRESENTATION AREAS
A	10,000	660,000	1,080,000	900,000	2,360,000	-
B	100,000	290,000	890,000	590,000	8,070,000	-
C	40,000	570,000	330,000	210,000	-	984,000
D	110,000	410,000	650,000	1,120,000	2,650,000	-
E	310,000	380,000	360,000	410,000	-	1,160,000
F	1,540,000	1,740,000	680,000	380,000	-	620,000
G	1,940,000	1,830,000	850,000	1,510,000	-	5,590,000
TOTAL	4,050,000	5,880,000	4,840,000	5,120,000	13,080,000	
PERCENT	12%	18%	15%	16%	39%	
OVERALL TOTAL						
= 32,970,000						
100%						

are producing an effluent of 10 mg/l BOD₅. For this condition, this table demonstrates that, for the entire Planning Area, approximately 12% of the BOD₅ would be contributed by point discharges, 18% by urban stormwater, 15% by grassland, 16% by cropland, and 39% by sources outside the Planning Area.

3. BOD₅ Condition 3. Table VI-3 provides a summary of the estimated annual BOD₅ loads if some of the major dischargers were to produce an effluent of 5 mg/l BOD₅; this condition represents one of the several options being considered during the 1977-1978 planning cycle. This table demonstrates that for this condition approximately 7% of the BOD₅ would be contributed by point discharges, 19% by urban stormwater, 16% by grassland, 16% by cropland, and 42% by sources outside the Planning Area.

4. Nitrogen. Table VI-4 provides a summary of the estimated annual nitrogen loads for the Planning Area. This table demonstrates that approximately 68% of the nitrogen is being contributed by point sources, 10% by urban stormwater, 4% by grassland, 6% by cropland, and 12% by sources outside the Planning Area.

5. Phosphorus. Table VI-5 provides a summary of the estimated annual phosphorus loads for the Planning Area. This table demonstrates that approximately 87% of the phosphorus is being contributed by point sources, 7% by urban stormwater, 1% by grassland, 2% by cropland, and 3% by sources outside the Planning Area.

TABLE VI-3

ESTIMATED ANNUAL LOADS--BOD₅ CONDITION 3

PRESENTATION AREA	BOD ₅ CONDITION 3 (kg/yr)						FROM OTHER PRESENTATION AREAS
	POINT SOURCE	URBAN STORMWATER	GRASSLAND	CROPLAND	FROM OUTSIDE 208 PLANNING AREA		
A	10,000	660,000	1,080,000	900,000	2,360,000	-	-
B	100,000	290,000	890,000	590,000	8,070,000	-	-
C	40,000	570,000	330,000	210,000	-	984,000	
D	110,000	410,000	650,000	1,120,000	2,650,000	-	
E	161,000	380,000	360,000	410,000	-	1,160,000	
F	780,000	1,740,000	680,000	380,000	-	620,000	
G	1,080,000	1,830,000	850,000	1,510,000		4,840,000	
TOTAL	2,281,000	5,880,000	4,840,000	5,120,000	13,080,000		OVERALL TOTAL = 31,201,000
PERCENT	7%	19%	16%	16%	42%		100%

TABLE VI-4

ESTIMATED ANNUAL LOADS--TOTAL NITROGEN

PRESENTATION AREA	TOTAL N (kg/yr)					FROM OUTSIDE 208 PLANNING AREA	FROM OTHER PRESENTATION AREAS
	POINT SOURCE	URBAN STORMWATER	GRASSLAND	CROPLAND			
A	7,600	165,000	90,000	104,000		346,000	-
B	110,000	70,000	81,000	68,000		817,000	-
C	104,000	145,000	30,000	24,000		-	635,000
D	247,000	100,000	114,000	250,000		536,000	-
E	845,000	95,000	63,000	911,000		-	716,000
F	3,700,000	440,000	62,000	43,000		-	290,000
G	5,064,000	460,000	149,000	335,000		-	5,891,000
TOTAL	10,079,600	1,475,000	597,000	915,000		1,699,000	
PERCENT	68%	10%	4%	6%		12%	
						OVERALL TOTAL = 14,765,600	
						100%	

TABLE VI-5
ESTIMATED ANNUAL LOADS--TOTAL PHOSPHORUS

PRESENTATION AREA	TOTAL P (kg/yr)					
	POINT SOURCE	URBAN STORMWATER	GRASSLAND	CROPLAND	FROM OUTSIDE 208 PLANNING AREA	FROM OTHER PRESENTATION AREAS
A	2,800	33,000	10,800	11,500	22,900	-
B	74,000	15,000	8,900	7,500	87,400	-
C	39,000	29,000	3,300	2,600	-	81,900
D	109,000	21,000	8,900	19,400	42,600	-
E	301,000	19,000	4,900	7,100	-	97,400
F	1,408,000	87,000	6,800	4,800	-	58,900
G	1,855,000	91,000	11,600	26,100	-	1,608,900
TOTAL	3,788,800	295,000	55,200	79,000	152,900	
PERCENT	87%		1%	2%	3%	100%
OVERALL TOTAL						= 4,370,900

6. Sediment. Table VI-6 provides a summary of the estimated annual sediment loads for the Planning Area. This table demonstrates that approximately 0.3% of the sediment or TSS is contributed by point sources, 5% by urban storm-water, 4% by grassland, 39.7% by cropland and 51% from outside the Planning Area. Essentially all the sediment from outside the Planning Area is retained in Lakes Lavon, Lewisville, Grapevine, and Benbrook.

7. Background Loading Levels. Through application of the background loading levels presented previously in Table V-6, preliminary estimates can be made of the approximate loading rates of BOD₅, nitrogen, phosphorus, and sediment which would occur for the Planning Area in the absence of human activity. These values are 7,000,000 kilograms/year for BOD₅, 610,000 kilograms/year for nitrogen, 61,000 kilograms/year for phosphorus, and 350,000,000 kilograms/year for sediment. These totals do not include contributions from sources outside the Planning Area.

B. Areawide Assessments.

The information presented thus far can be displayed in several different manners to emphasize certain major points. For example, Figures VI-1, VI-2, and VI-3 have been constructed to demonstrate the relative magnitudes of point and nonpoint sources of BOD₅ on an annual basis for each of the presentation areas for the three BOD₅ Conditions. These illustrations present: 1) the relative magnitude of five-day

TABLE VI-6
ESTIMATED ANNUAL LOADS--SEDIMENT

PRESENTATION AREA	SEDIMENT (kg/yr)					
	POINT SOURCE	URBAN STORMWATER	GRASSLAND	CROPLAND	FROM OUTSIDE 208 PLANNING AREA	FROM OTHER PRESENTATION AREAS
A	20,000	40,000,000	54,000,000	382,000,000	242,500,000	-
B	350,000	17,000,000	45,000,000	249,000,000	2,045,100,000	-
C	200,000	35,000,000	17,000,000	87,000,000	-	9,000,000
D	310,000	25,000,000	45,000,000	665,000,000	1,130,000,000	-
E	1,570,000	23,000,000	25,000,000	242,000,000	-	8,600,000
F	7,990,000	106,000,000	34,000,000	159,000,000	-	15,200,000
G	10,450,000	111,000,000	60,000,000	892,000,000	-	182,900,000
TOTAL	20,890,000	357,000,000	280,000,000	2,676,000,000	3,417,600,000	
PERCENT	0.3%	5%	4%	39.7%	51%	100%
OVERALL TOTAL = 6,751,490,000						

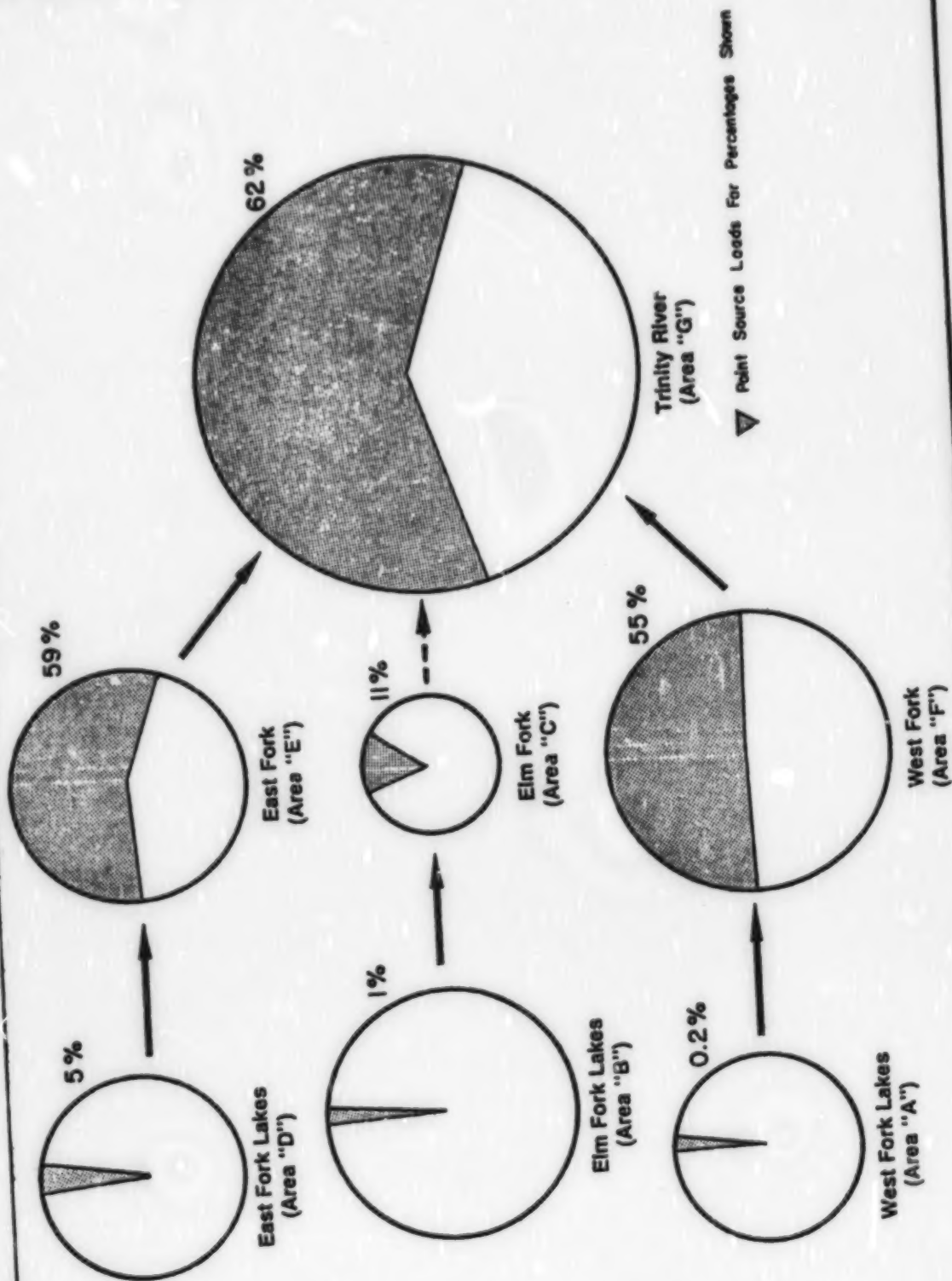


FIGURE VI-1
POINT AND NONPOINT SOURCE COMPARISON :
BOD₅ LOADS FOR CONDITION I

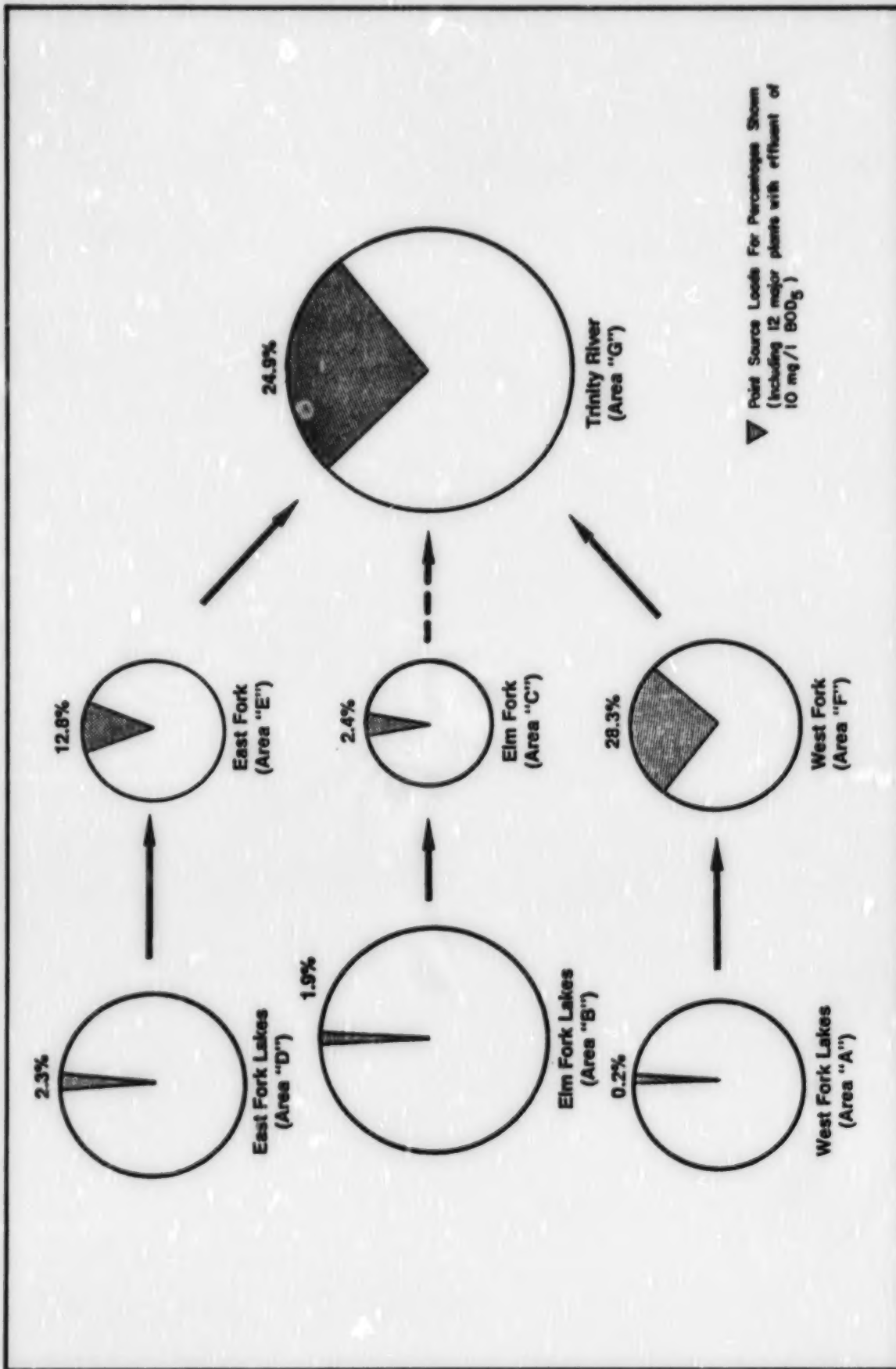


FIGURE VI-2
POINT AND NONPOINT SOURCE COMPARISON:
BOD₅ LOADS FOR CONDITION 2

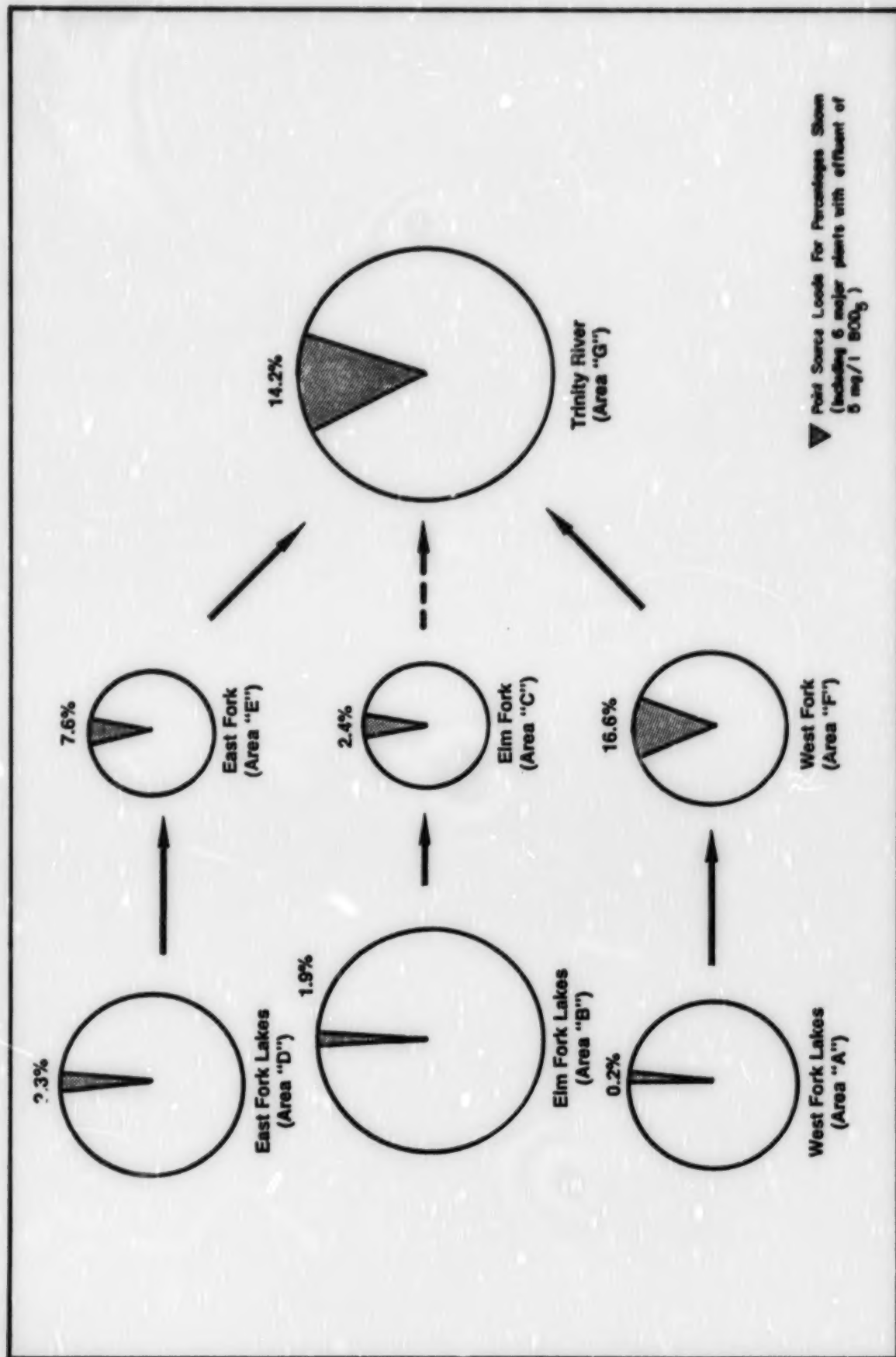


FIGURE VI-3
POINT AND NONPOINT SOURCE COMPARISON :
BOD₅ LOADS FOR CONDITION 3

BOD loads entering or being generated within each Presentation Area as indicated by the size of the circle; 2) the percent of nonpoint source load entering and or being generated within each Presentation Area, and 3) the percent of point source load entering or being generated within each Presentation Area. In these calculations, consideration was given to the decay of some of the BOD₅ in each Presentation Area. These approximations will be further refined during water quality modeling studies which are being conducted by NCTCOG as part of the 1977-1978 planning cycle. In the comparison of point and nonpoint sources, areas of particular interest are Presentation Area E--Lower East Fork, Presentation Area G--West Fork, and Presentation Area G--Upper Trinity River. These areas contain the six major wastewater treatment plants for which the point source loading Condition 3 was defined. These three presentation areas can be evaluated as follows.

1. Presentation Area E--East Fork. Based on 1975-1976 BOD₅ point source loading Condition 1 and the preliminary nonpoint source five-day BOD load calculations, the point sources represent 59% and the nonpoint sources represent 41% of the total annual BOD₅ load.

Applying the point source loading Condition 2 derived from waste treatment improvements now being implemented and the preliminary nonpoint source five-day BOD load calculations, the point sources represent 13% and the nonpoint sources represent 87% of the total load. Providing this advanced

level of treatment will result in 53% reduction in total five-day BOD load from the overall 1975-1976 load.

Applying the point source loading Condition 3, which is being considered as one of the several future options, and the preliminary nonpoint source five-day BOD load calculations, the point sources would represent 8% and the nonpoint sources would represent 92% of the total load. Providing this more advanced level of treatment would result in an additional 6% reduction in the overall annual five-day BOD load to this portion of the East Fork when compared with the point source loading Condition 2.

The results of preliminary calculations of annual five-day BOD loads discharged to the East Fork by nonpoint sources and the loads from the two major treatment plants under various effluent quality conditions are presented in Figure VI-4. This figure graphically illustrates the reductions in five-day BOD discussed above and the relative magnitude of the remaining nonpoint source loads for this presentation area.

2. Presentation Area F--West Fork. Based on 1975-1976 reported point source discharge data and preliminary nonpoint source five-day BOD load calculations, the point sources represent 55% and the nonpoint sources represent 45% of the total annual load.

Based on the point source loading Condition 2, which is presently being implemented, and the preliminary nonpoint source five-day BOD load calculations, the point sources

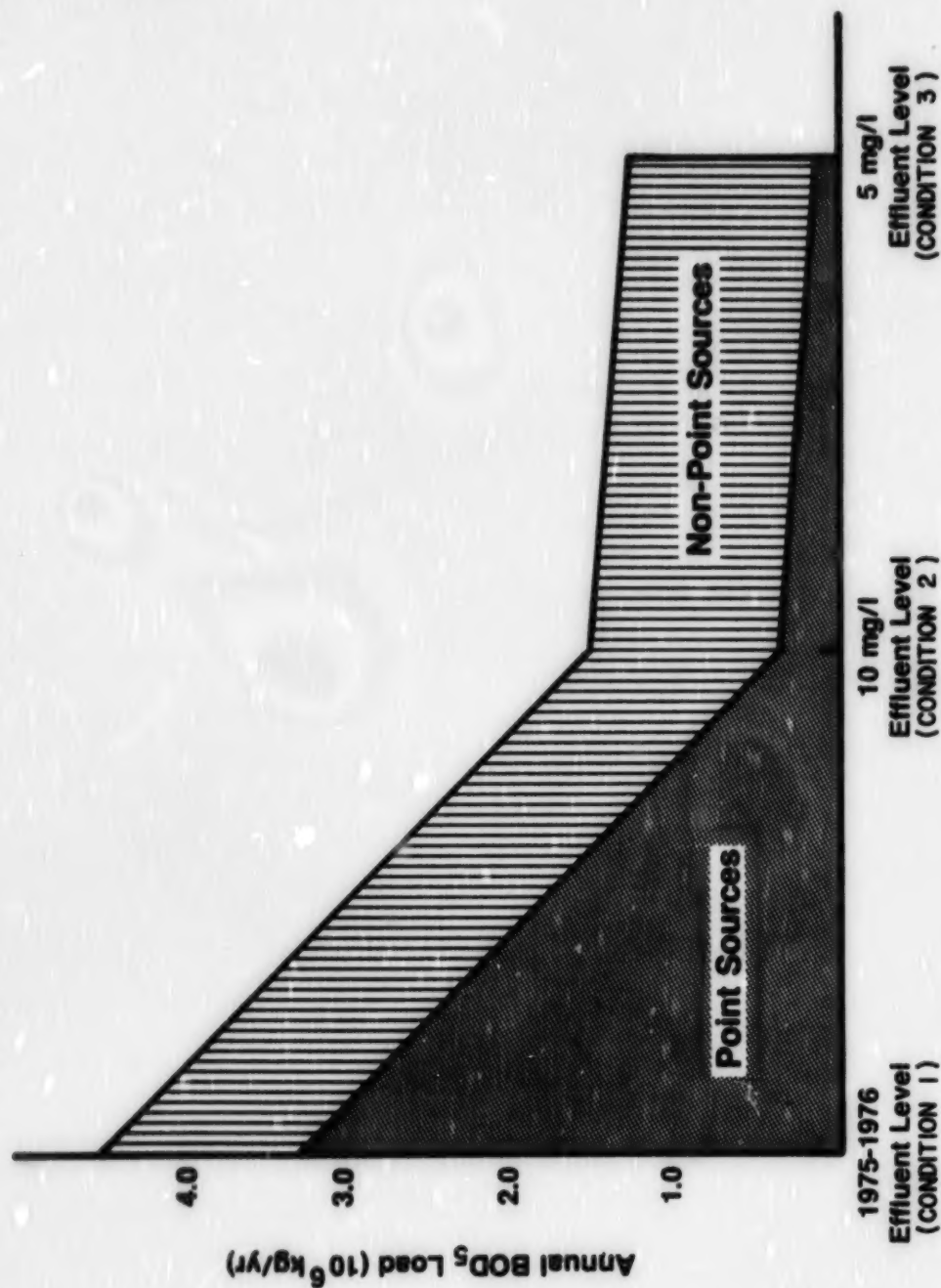


FIGURE VI-4
ANNUAL BOD₅ LOADS DISCHARGED
TO THE EAST FORK FOR
VARIOUS EFFLUENT LEVELS

represent 28% and the nonpoint sources represent 72% of the total load. Providing this advanced level of treatment will result in about a 33% reduction in total five-day BOD load as compared to the 1975-1976 BOD₅ point source loading Condition 1.

Based on the more stringent point source loading Condition 3, which is being considered as one of several future options, and the preliminary nonpoint source five-day BOD load calculations, the point sources would represent 17% and the nonpoint sources would represent 83% of the total load. Providing this more advanced level of treatment would result in an additional 14% reduction in the total annual five-day BOD load in this portion of the West Fork when compared with the point source discharge level for the point source loading Condition 2.

3. Presentation Area G--Trinity River. Based on 1975-1976 BOD₅ point source loading Condition 1 and the preliminary nonpoint source five-day BOD load calculations, the point sources represent 62% and the nonpoint sources represent 38% of the total load.

Based on the point source loading Condition 2, which is presently being implemented and preliminary nonpoint source five-day BOD load calculations, the point sources represent 25% and the nonpoint sources represent 75% of the total load. Providing this advanced level of treatment would result in about a 49% reduction in total five-day BOD load from the 1975-1976 point source loading Condition 1.

Based on the point source loading Condition 3, which is being considered as one of several future options, and preliminary nonpoint source five-day BOD load calculations, the point sources would represent 14% and the nonpoint sources would represent 86% of the total annual load. Providing this more advanced level of treatment would result in about an additional 11% reduction in the total five-day BOD load in this portion of the Trinity River when compared with the point source loading Condition 2.

C. Materials Balances.

Another aid in developing a perspective regarding point and nonpoint sources in an area is to perform a materials balance for each major constituent. Initial estimates of the movement of BOD₅, nitrogen, phosphorus, and sediment through the seven presentation areas are presented in Figures VI-5, VI-6, VI-7, and VI-8. These figures are intended to illustrate the sources and pathways of the loads presented previously in Tables VI-1, VI-4, VI-5, and VI-6. These calculations are at a preliminary stage and will be defined during the remainder of the study period.

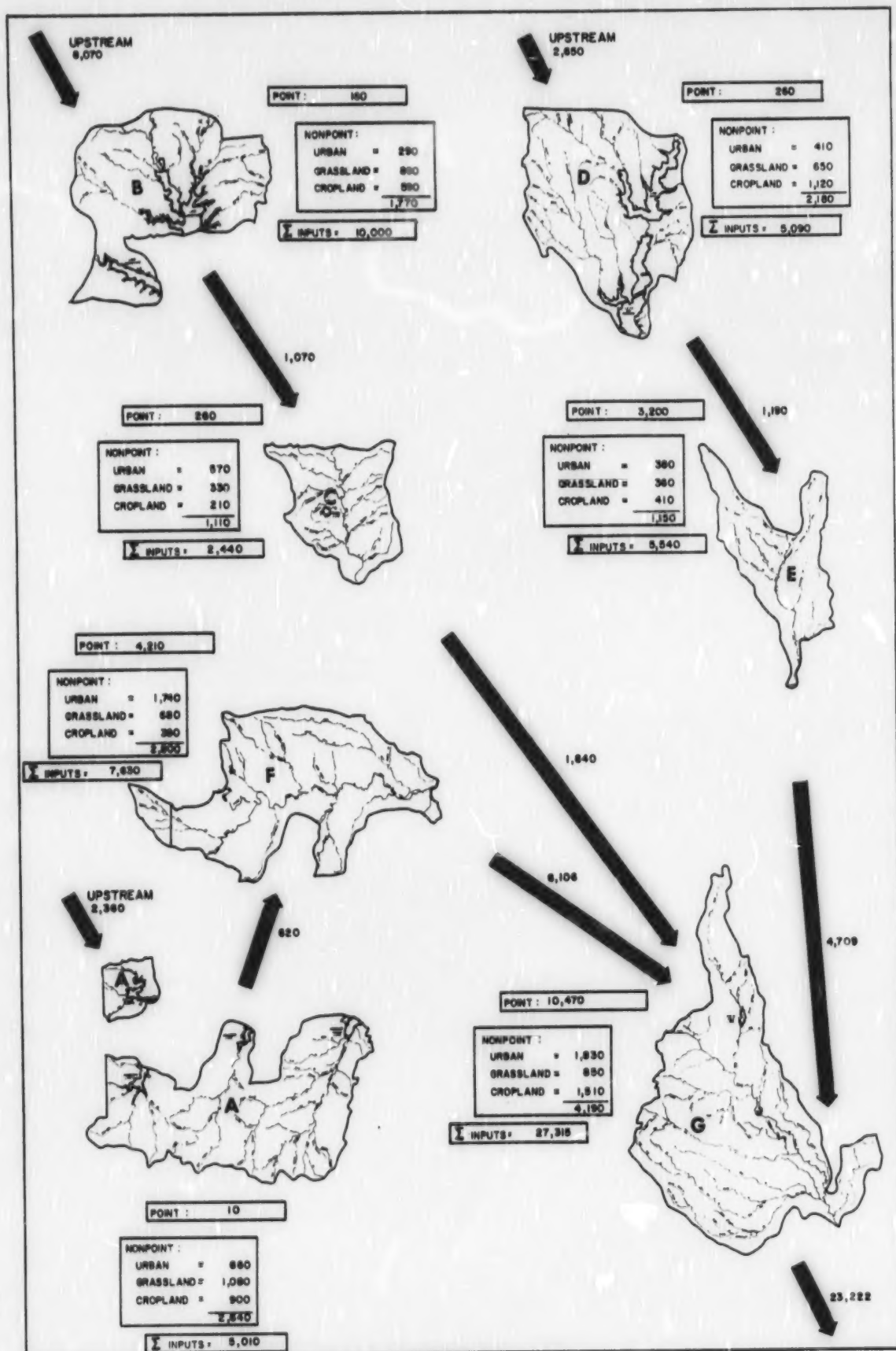


FIGURE VI-5
MATERIAL BALANCE FOR
BOD₅ (THOUSAND kg/yr)

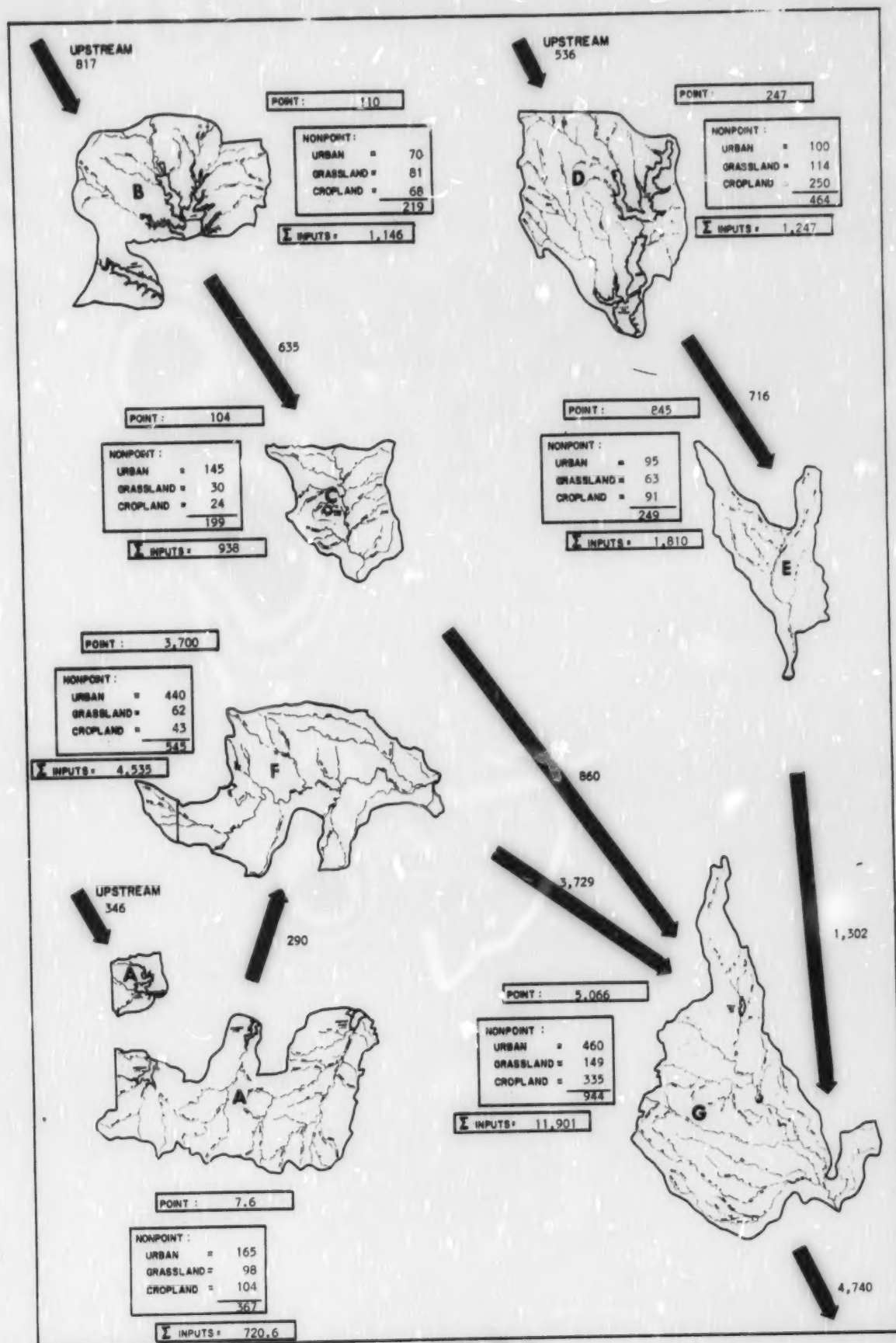


FIGURE VI-6
MATERIAL BALANCE FOR
NITROGEN (THOUSAND kg/yr)

VI-21

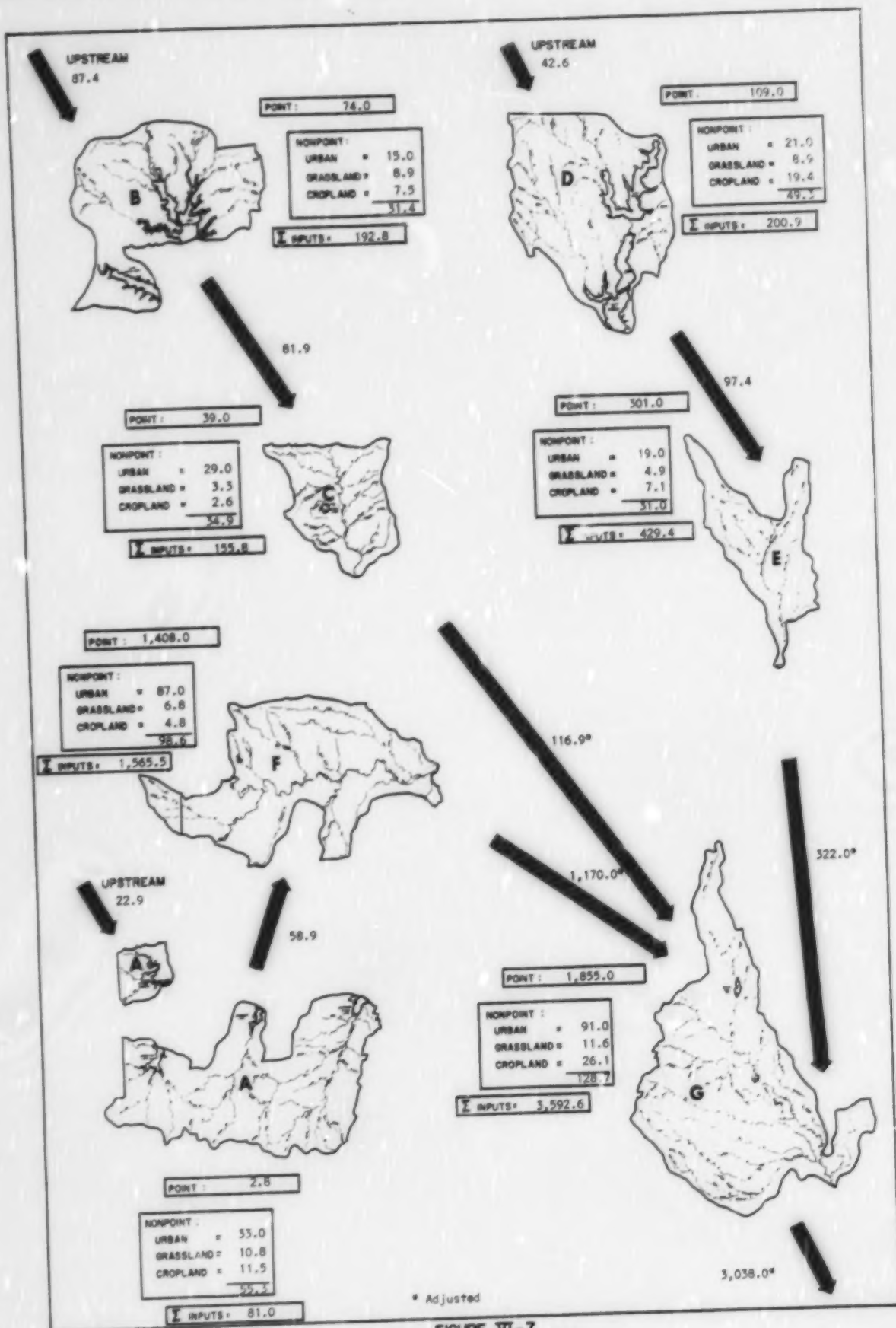


FIGURE VI-7
 MATERIAL BALANCE FOR
 PHOSPHORUS (THOUSAND kg/yr)

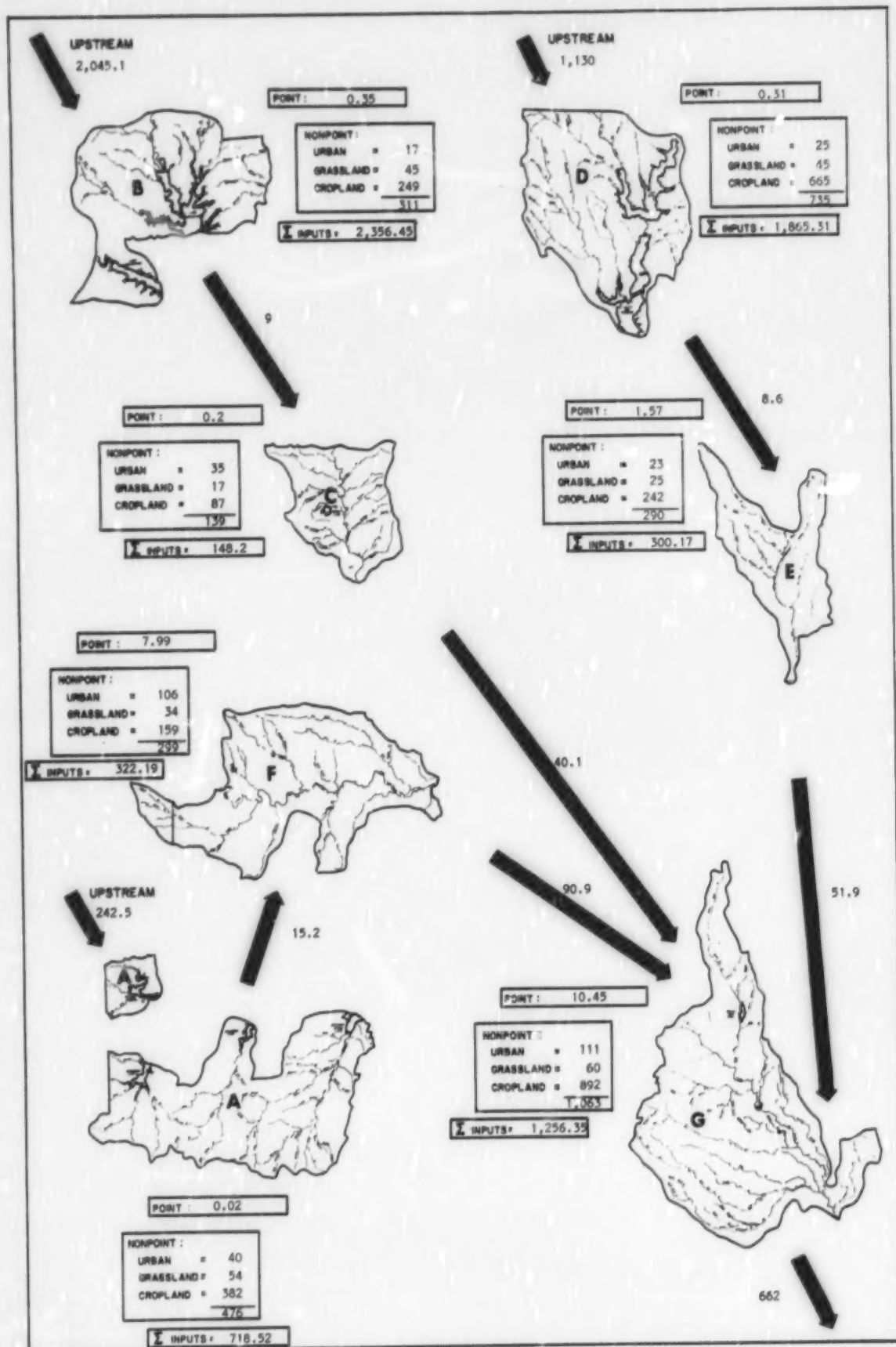


FIGURE VI-8
MATERIAL BALANCE FOR
SEDIMENT (MILLION kg/yr)

CHAPTER VII
OTHER SOURCES AND OTHER POLLUTANTS

CHAPTER VII

OTHER SOURCES AND OTHER POLLUTANTS

The purpose of this chapter is to briefly discuss pollutant sources other than the five major categories evaluated previously and types of pollutants other than BOD₅, nitrogen, phosphorus, and sediment.

A. Other Sources.

Other sources of pollutants in the Planning Area include landfills, septic tanks, feedlots, resource extraction, and construction. Although these sources may cause localized pollution problems, it is anticipated that their overall effect will be small when compared with the major land use designations and point sources discussed earlier. Some perspective into the potential impact of these sources is gained by observing the amount of land utilized or number of operations which exist in the Planning Area. Table VII-1 lists the land fill area, the population served by septic tanks, and the additional unsewered population for each of the presentation areas. The feedlots existing in the Planning Area are identified in Table VII-2. The two sand and gravel operations in the area are shown in Table VII-3.

Roadway and residential construction often causes a noticeable amount of sediment runoff. Sufficient information was available on roadway construction in the Planning Area to develop some preliminary calculations of potential

TABLE VII-1
LANDFILL AND SEPTIC TANK USAGE
IN THE PLANNING AREA

<u>Presentation Area</u>	<u>Landfill Area¹ (km²)</u>	<u>Population Served by Septic Tanks² (capita)</u>	<u>Additional Population Unsewered² (capita)</u>
A	1.46	13,956	422
B	0.44	3,282	63
C	2.97	1,264	287
D	0.46	3,632	323
E	1.86	2,627	251
F	3.46	32,587	1,855
G	5.62	32,504	4,521
TOTAL	16.27	89,852	7,722

¹ Reference 22.

² References 23, 24.

TABLE VII-2
 CONFINED FEEDING LIVESTOCK OPERATIONS
 IN THE PLANNING AREA¹

<u>NAME</u>	<u>COUNTY</u>	<u>PRESENTATION AREA</u>	<u>WASTE CONTROL ORDER</u>	<u>FEEDLOT AREA (hectares)</u>	<u>HEAD OF CATTLE</u>	<u>HEAD OF SWINE</u>	<u>WASTEWATER (liters/day)</u>
Hershel Matthews	Tarrant	A	20058	0.38		320	1,900
Blue Ribbon Company	Denton	B	01845	0.97	750		
Kelly Hog Farm	Kaufman	E	20078	0.99		335	570
W.E. Featherston	Kaufman	E	20064			600	
Graves Feedlot	Ellis	G	01512		1,000		
Johnson Hog Farm	Ellis	G	20010	0.87		1,180	11,400
Ryrd Trusts Feedlot	Dallas	G	01456	8.4 ²	3,000		
John F. Tufts Dairy	Dallas	G	01739	2.0	400		

¹ References 23, 25.

² Total area served by retention ponds; may include areas other than feedlot.

TABLE VII-3

RESOURCE EXTRACTION OPERATIONS
IN THE PLANNING AREA*

<u>NAME</u>	<u>COUNTY</u>	<u>PRESENTATION AREA</u>	<u>TYPE</u>	<u>WASTE CONTROL ORDER</u>
Austin Road County Worth Construction	Denton	B	Sand/Gravel	1285
Gifford-Hill	Dallas	G	Sand/Gravel	397

*Reference 23.

TABLE VII-4
KILOMETERS OF ROADWAY CONSTRUCTION
BY PRESENTATION AREA¹

PRESENTATION AREA	A	B ²	C	D ³	F	F	G	TOTAL
Completed or Under Contract 1975-1976								
1 lane	0	0	0	0	0	0	0.8	0.8
2	13.5	0	3.4	1.6	0	4.2	8.5	31.2
3	0	0	0	3.7	0	0	0	3.7
4	16.4	2.4	6.4	10.0	10.3	36.5	33.1	115.1
6	29.5	0	17.5	10.8	17.4	19.0	29.3	123.5
7	0	0	0	0	0	1.9	0	1.9
8	8.5	0	7.3	0	0	0	0	15.8
Subtotal	67.9	2.4	34.6	26.1	17.7	61.6	71.7	292.0
1977								
1 lane	0	0	21.7	1.6	0	43.5	57.9	124.7
2	0	0	0.8	4.4	0	24.8	0	30.0
4	7.1	2.6	10.0	8.0	7.4	31.4	8.1	74.6
6	2.9	0	13.4	5.9	2.4	18.3	15.9	58.8
8	0	0	5.8	0	0	0	4.2	10.0
Subtotal	10.0	2.6	51.7	19.9	9.8	118.0	86.1	298.1
TOTAL	77.9	5.0	96.3	46.0	37.5	179.6	157.8	590.1

¹ Reference 26.

² Only about 15% of Presentation Area included in transportation study.

³ Only about 50% of Presentation Area included in transportation study.

TABLE VII-5
ESTIMATE OF SEDIMENT PRODUCED BY ROADWAY
CONSTRUCTION IN THE PLANNING AREA

PRESENTATION AREA	Kilograms of Sediment Yielded ¹		
	1975-76	1977	Average Annual
A	104,000,000	17,000,000	40,000,000
B ²	4,000,000	4,000,000	3,000,000
C	56,000,000	69,000,000	42,000,000
D ³	40,000,000	29,000,000	23,000,000
E	47,000,000	17,000,000	21,000,000
F	101,000,000	143,000,000	81,000,000
G	114,000,000	47,000,000	70,000,000
TOTAL	466,000,000	376,000,000	280,000,000

¹ These figures based on estimated kilometers of construction (Table VII-4) and total construction project loading values of 850,000 kg/km of road for 2 lanes or less or 1,700,000 kg/km of road for 4 lanes or greater (Ref. 27).

² Only about 15% of Presentation Area included in transportation study.

³ Only about 50% of Presentation Area included in transportation study.

sediment loading from these activities. Table VII-4 provides a summary of the length and number of lanes of ongoing road construction in the area. By applying a sediment loading rate based upon specialized studies of roadway construction activities⁽²⁷⁾, an estimate was made of the potential sediment yield from these activities in the Planning Area. The results of these calculations are shown in Table VII-5. As shown on the table, the average annual load of sediment from local roadway construction was estimated as 280 million kilograms. This weight of sediment amounts to about 5 percent of the total sediment load calculated previously for the entire Planning Area.

B. Other Pollutants.

This category includes pollutants for which data are insufficient to allow the evaluation of overall loading rates or source identification. These pollutants include coliform bacteria, heavy metals, and toxic chemicals. Ongoing sampling studies should provide some insight into appropriate values in runoff for these parameters. The potential impact of these parameters will be discussed briefly in the next chapter.

CHAPTER VIII
WATER QUALITY IMPACTS

CHAPTER VIII

WATER QUALITY IMPACTS

The purpose of this chapter is to present a brief discussion of water quality impacts caused by nonpoint sources. This discussion will be qualitative in nature and is designed to provide a perspective regarding the potential present and future water quality problems which may be associated with nonpoint pollutant sources in the Designated Planning Area. A more quantitative assessment of these impacts is scheduled to be undertaken by NCTCOG and its consultants in the completion of separate contracts associated with NCTCOG's planning activities related to the requirements of Section 208 of PL 92-500.

A. Role of Human Activities.

In the absence of human activity in an area, a certain amount of material would still be transported in the runoff from the land surface. This natural occurrence is often termed a "background," "natural," or "pastoral" pollutant level. In this terminology, the word "pollutant" is used in a general sense, simply meaning some material which is added to the water. In this sense, the word "pollutant" does not necessarily carry a negative connotation since certain amounts of these substances are needed to sustain life in water bodies. Human activities tend to add significant amounts of material to the runoff in addition to these background levels; these human activities include

urbanization, waste disposal, development of agricultural and grazing lands, resource extraction, and modifications to the water course. These activities may cause significant degradation of the quality of the receiving bodies of water. This degradation must be judged relative to naturally occurring conditions, the intended use of the water body, aesthetics, and the existing water quality standards.

B. Consideration of Time and Space Scales.

An evaluation of water quality impacts requires an understanding of the time scales and space scales of importance to the particular pollution problem. Some pollutants cause acute water quality problems for only several hours in a confined area and then are dissipated by dilution or decay. Other pollutants cause chronic, widespread water quality problems as a result of cumulative effects over a number of years; these chronic effects are of special concern in natural or man-made holding areas such as large estuaries or impoundments. Because of the different time and space scales for various types of water quality impacts, studies to evaluate or control degradation of water quality must be designed with the scale in mind which is proper for the parameter being studied. The time and space scales appropriate to runoff-related pollution are illustrated in Figures VIII-1 and VIII-2.

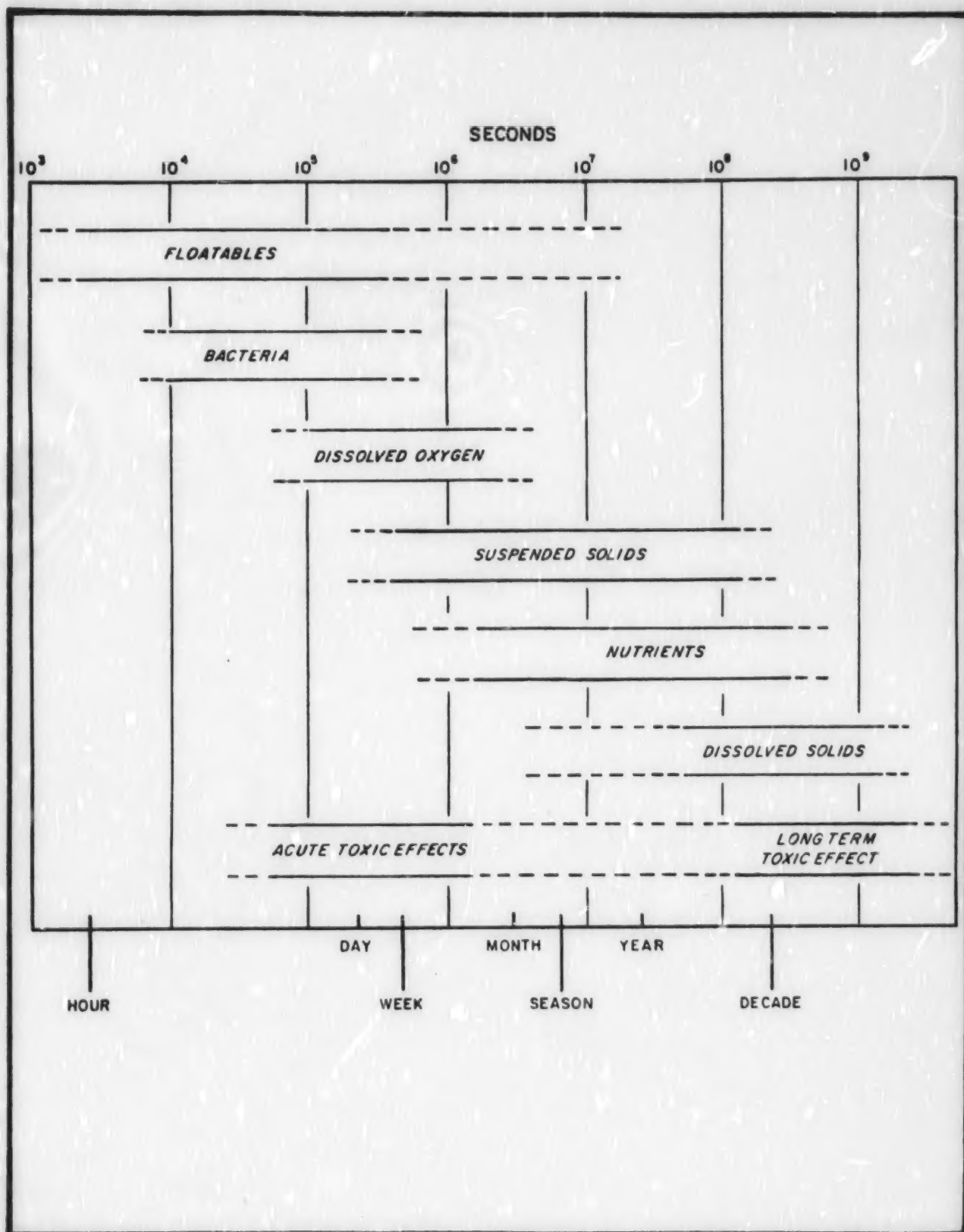


FIGURE VIII - 1
TIME SCALES
STORM RUNOFF WATER QUALITY PROBLEMS

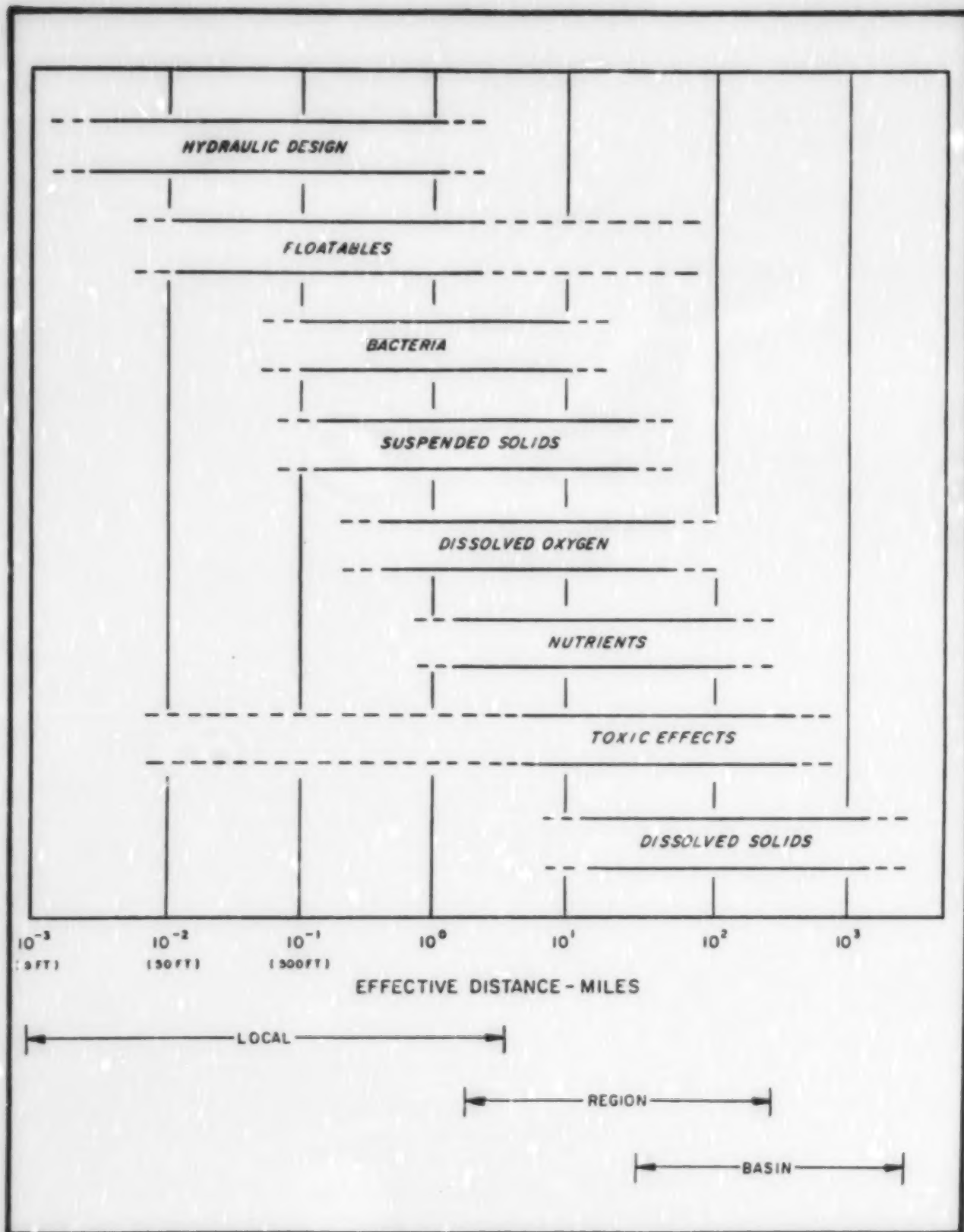


FIGURE VIII-2
SPACE SCALES
STORM RUNOFF WATER QUALITY PROBLEMS

The input of runoff to the natural and man-made water conveyance systems in a region can have a number of effects. Specifically these effects include: the physical, addition of water, which through surging may resuspend pollutants into the water from channel sediments; the flushing of solids and solubles from open ground, cropland, street surfaces, and sewers; and the leaching of materials as some of the rain water percolates through the soil to the groundwater. If some of the runoff is carried through a municipal sewage treatment plant, waste removal efficiencies may decrease with the increased flow. All of these effects can have multiple water quality impacts, depending upon the materials which are added or resuspended. The quality of the water system in its natural state as well as the separate effects of point sources must be considered in order to evaluate the added impact of the runoff.

In the following sections, discussions of the impacts of specific pollutants will be presented, based upon the preliminary calculations reported earlier in this document. For BOD, nutrients, and sediments, these discussions will include three points: general impacts, impacts on local lakes, and impacts on local streams. These discussions are meant only as a preliminary coverage of the subject. Several comments will also be presented regarding other pollutants such as coliforms, heavy metals, and toxicants.

C. Biochemical Oxygen Demand (BOD).

1. General Impacts. A certain amount of BOD can be accommodated in natural water bodies without causing water quality problems. However, high BOD concentrations can bring about large depletions of oxygen which will severely limit the ability to maintain a well-balanced aquatic ecosystem. In the extreme, dramatic fish kills can occur when dissolved oxygen levels drop below 2 or 3 mg/l. Depletions of dissolved oxygen are caused by the decay, or oxidation, of the BOD. The first order exponential oxidation rate of BOD in water bodies typically has values between 0.1/day to 1.0/day; a widely used rate for municipal waste is 0.25/day. With these decay rates, 20% of an initial load would still remain in the receiving body of water after approximately 1.6 to 16 days. Thus, for intermittent BOD loadings, effects of heavy BOD loads might be expected to last for at least this period of time and for a corresponding distance downstream. Significant oxygen depletions can also occur as a result of the suspension of organic benthic deposits from the river channel bottoms or through a slug of water devoid of dissolved oxygen entering the receiving waters during the "first flush" from the storm sewers or sanitary sewer overflows.

For this interim report, BOD_5 was used as a measure of oxygen demand because most local and national data emphasize this parameter. However, in future studies,

ultimate oxygen demand (UOD) should be used as a more representative measure of the actual oxygen demanding characteristics of pollutants.

2. Impacts on Local Lakes. Approximately 47 million kilograms of BOD₅ per year presently enter or are generated within the Planning Area. Of this amount, approximately 21 million kilograms per year, or 45%, enter the lakes. Of the amount of BOD₅ which enters the lakes, approximately 13 million kilograms per year, or 62%, comes from sources outside the Planning Area. Although some of the lakes, such as Lake Ray Hubbard, receive significant point source discharges, most of the BOD₅ which enters the lakes is produced by nonpoint sources, particularly cropland and grassland.

The lakes are generally considered to be in good condition relative to dissolved oxygen standards. (10,28) Oxygen depletion does occur in the lower layers of some of the lakes during stratified conditions and significant diurnal oxygen variations have been observed at times due to algal activities.

3. Impacts On Streams. At present, the predominant contributors of BOD₅ to the local streams are point sources. This is particularly true of the East Fork, West Fork, and main stem Trinity River, where over 55% of the annual BOD₅ load is contributed by point sources. This situation has caused severe oxygen depletion in the rivers, particularly during summer low flow conditions.

Present and anticipated treatment plant modifications will reduce these point source contributions to such a level that nonpoint sources will generate the largest percentage of BOD₅ in these areas on an annual basis. Thus, primary attention must be given to the potential impact of these nonpoint source BOD₅ loads relative to the future impacts of point sources.

D. Nutrients.

1. General Impacts. A group of organic and inorganic compounds, chiefly nitrogen and phosphorus forms, act as nutrients for aquatic organisms. Discharge of these compounds into a receiving water body from point sources or runoff can stimulate excessive growth of these organisms or shift the make-up of the plant population towards more undesirable forms. Excessive growth can cause development of algal mats and large beds of rooted plants, which are unsightly and inhibit boating and swimming. Excessive amounts of algae or other aquatic plants may cause objectionable odor problems during warm summer months when recreational demand is highest. Severe eutrophication can greatly diminish the recreational and commercial potential of a water body, affecting shoreline property values as well. Algae can also cause taste problems for drinking water supplies. Furthermore, extreme diurnal dissolved oxygen fluctuations can be caused by excessive concentrations of algae and aquatic plants; these

fluctuations can cause violations of standards and stress in aquatic organisms.

Stormwater can often carry large amounts of these nitrogen and phosphorus forms, both from agricultural runoff, which might carry fertilizers as well as humus, and from urban runoff, which might carry a wide range of chemicals from street litter and storm sewers.

The time considerations for nutrient loading impacts can be on the order of seasons to years, and spatial considerations may involve hundreds of miles. The soluble and settleable forms of nitrogen and phosphorus can become nutrient sources for plankton and rooted aquatic plants. Once these nutrients are incorporated into the food chain, there is generally little loss from the system. Thus, nutrient loadings can have a cumulative effect over a period of years. Similarly, transportation of nutrients downstream to impoundments or estuaries can promote eutrophication of areas far removed from the actual point of discharge.

2. Impacts On Local Lakes. Approximately 15 million kilograms of nitrogen per year presently enter or are generated within the Planning Area. Of this amount, approximately 3 million kilograms per year, or 20%, enter the lakes in the Planning Area. Of the amount of nitrogen which enters the lakes, approximately 1.7 million kilograms per year, or 57%, comes from sources outside the Planning Area.

Approximately 4.4 million kilograms of phosphorus per year presently enter or are generated within the Planning Area. Of this amount, approximately 0.5 million kilograms per year, or 11%, enter the lakes in the Planning Area. Of the amount of phosphorus which enters the lakes, approximately 30% comes from sources outside the Planning Area.

Both point and nonpoint sources contribute significant portions of the nutrient loads to lakes in the Planning Area. In general, nonpoint sources contribute a higher percentage of the nutrients entering each of the lakes. An exception to this condition is Lake Ray Hubbard, which receives most of its nutrients from point sources.

Apparently some eutrophication problems associated with excessive nutrient concentrations have been experienced in some area lakes, (10,28) including Lake Arlington, Lake Ray Hubbard, Lake Lavon, and Lake Lewisville. These conditions have included substantial phytoplankton communities and associated taste and odor problems.

3. Impacts On Local Streams. Point source discharges contribute most of the nutrients to the West Fork, East Fork, and main stem Trinity River. Additional amounts of nutrients are contributed by nonpoint sources in these areas or from upstream lake discharges. These conditions lead to high levels of nutrients in the river waters within the portion of the Planning Area downstream of the lakes. Furthermore, these conditions lead to the export of a large amount of nutrients to the Trinity Basin downstream of the Planning Area;

much of this nutrient load is eventually transported to Lake Livingston.

E. Sediments and Suspended Solids.

1. General Impacts. The addition of suspended solids to water bodies can have a number of water quality impacts. In the suspended state, these substances can increase turbidity and can be aesthetically objectionable. As they settle, they may build up a sediment layer which affects benthic organisms. If the sediments are organic in nature, they may exert an oxygen demand. An accelerated rate of sedimentation leads to rapid filling in of impoundments, impairs river flow, and contributes to flood potential.

Large suspended solids loads are often associated with runoff from storms. Overland flow can dislodge soil particles and organic debris and carry them to the receiving water. In urban areas, accumulated dirt and debris from paved surfaces and from inside storm sewers can be flushed and carried to the receiving water body. These materials may settle out immediately or be carried a long distance downstream. Thus, the spatial influence of suspended solids may extend much farther than that of the D.O. problem. In addition, the time scale may be much larger, as the impact of a suspended solids loading may not be felt from an individual storm, but rather from the cumulative effects of many storms.

2. Impacts On Local Lakes. Approximately 6.7 billion kilograms of sediment per year presently enter or are generated within the Planning Area. Of this amount,

approximately 3.4 billion kilograms per year, or 51%, comes from sources outside the Planning Area. Essentially all of this sediment from outside the Planning Area is trapped in Lakes Benbrook, Grapevine, Lewisville, and Lavon. Of the sediment which is generated within the Planning Area, most appears to come from cropland areas.

In the design and construction of impoundments within the Planning Area, a certain portion of the reservoir capacity was allocated for sediment collection, based on anticipated rates of sediment loading. Some of these impoundments, such as Grapevine Lake,⁽¹⁶⁾ appear to be filling with sediment at a lower rate than originally anticipated, and some of these impoundments, such as Lewisville Lake,⁽¹⁷⁾ appear to be filling with sediment at a much greater rate than originally anticipated.

3. Impacts On Local Streams. Of the sediment generated in the Planning Area downstream of the lakes, approximately 76% comes from cropland areas, 8% from grassland areas, 15% from urban stormwater, and 1% from point sources. Essentially all this sediment is eventually carried downstream and out of the area during high runoff events.

Although point sources produce the lowest volume of suspended solids relative to other sources, the impact of these point discharges is significant because of the high organic content of these solids. As these substances

settle out, the resulting benthal deposits cause oxygen depletions in many sections of the East Fork, West Fork, and main stem Trinity River. The anticipated improvements in waste treatment in the Planning Area should help to eliminate much of this problem. The role of urban runoff and other nonpoint sources in causing organic benthal deposits has not been quantified in any studies for the Planning Area.

F. Other Pollutants.

Several additional pollutants can cause water quality problems as a result of point or nonpoint discharges. The potential impact of these pollutants, including bacteria, metals, and toxic compounds, will be briefly discussed below. The loading rates of these pollutants from point and nonpoint sources in the Planning Area have not yet been determined. Ongoing sampling studies in the area should provide additional information which may lead to estimates of the magnitude of these loading rates and which may help in determining the relative contributions of point and nonpoint sources.

1. Coliform Bacteria, Viruses and Pathogenic Organisms.

Contamination of waterways by these organisms can pose a threat to public health. Both short-term and chronic contamination can adversely affect bathers and those who use the waterway as a supply of drinking water; this contamination can also render fish and shellfish unfit to eat. In Texas,

fecal coliform bacteria are often used as indicators for this group. When concentrations (organisms/100 ml) of these organisms rise above certain levels, the use of swimming and fishing areas can be restricted. Water quality standards in Texas are based on the geometric mean of a series of samples; in most areas, the standards are set between 200 and 2000 organisms/100 ml for fecal coliforms.

Concentrations of coliform bacteria have been shown to decrease in a first order exponential die-off pattern after introduction to river waters. Die-off rates typically range from 1.0/day to 3.0/day. With these die-off rates, approximately 20% of an initial pulse load of bacteria would remain after twelve to thirty-six hours. This indicates that the time scale of the coliform bacteria impact is of fairly short duration.

The spatial effects of the coliform phenomenon may also be somewhat limited. Assuming the above range of rates and a free-flowing stream velocity of 1 foot per second, only 20% of the input load would remain at a distance of 8 to 24 miles downstream.

High levels of fecal coliforms are an obvious problem in the main stem and major forks of the Trinity River in the Planning Area.^(10,28) The contributions of these organisms by Planning Area nonpoint sources, such as urban runoff and pastures, cannot be discerned from past data.

2. Metals and Toxicants. Many metals, such as iron, chromium, copper, and zinc, are required by aquatic organisms in trace amounts. However, when instream or sediment concentrations become too high, these metals can be toxic. In addition, other metals such as arsenic and lead and compounds such as cyanide, pesticides and chlorinated hydrocarbons can be highly toxic, even in small amounts. In general, these compounds are persistent and do not decompose readily. Rather, these materials accumulate in the water and sediment systems to exert deleterious effects over long periods of time.

Stormwater discharges can contribute these toxicants through leaching, agricultural runoff, and urban runoff. Buildup of toxicants in a water body or sediments can occur from repeated stormwater discharges over a period of years.

The impact of these substances on aquatic life in the Planning Area has not been thoroughly analyzed. However, a moderate amount of data is available⁽¹⁰⁾ for the main stem Trinity River water and sediments. These data indicate that the levels of some substances such as cadmium, chlordane, chromium, copper, dieldrin, fluoride, iron, lindane, manganese, mercury, phenol, and zinc are high relative to various guidelines for recommended limits for aquatic life^(2,29,30,31,32,33), benthal deposits⁽³⁴⁾, or drinking water standards.^(2,29,33,35)

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APPENDIX A
CONVERSION FACTORS

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<u>METRIC UNIT</u>	<u>MULTIPLIED BY</u>	<u>EQUALS</u>
cm	0.3937	in
cm/hr	0.3937	in/hr
kg	2.205	lb
kg/hr	2.205	lb/hr
kg/day	2.205	lb/day
kg/yr	2.205	lb/yr
km	0.6214	mi
km ²	0.3861	mi ²
km ²	247.1	acre
kg/km ² -yr	5.711	lb/mi ² -yr
kg/km ² -yr	0.008924	lb/acre-yr
liter	0.03531	cu ft
liter	0.2642	gal
liter	1.057	qt
liter (water)	2.205 (approx.)	lb
liter (water)	1000 (approx.)	gm
liter (water)	1 (approx.)	kg
liter/day	0.2624	gal/day
m	3.281	ft
m	39.37	in
m ²	10.76	ft ²
m ³	35.31	cu ft
m ³	264.2	gal
m ³ (water)	2205 (approx.)	lb

CONVERSION FACTORS (Cont.)

<u>METRIC UNIT</u>	<u>MULTIPLIED BY</u>	<u>EQUALS</u>
m ³ (water)	1000 (approx.)	kg
m ³ /sec	35.31	cfs
m ³ /sec	70.02	acre-ft/day
m ³ /sec	8.64×10 ⁷	liter/day
m ³ /sec	22.82	mgd
m ³ /sec	15,850	gpm
mg/l	1	g/m ³
<u>ENGLISH UNIT</u>	<u>MULTIPLIED BY</u>	<u>EQUALS</u>
acre	0.001562	mi ²
acre	.004047	km ²
acre-ft	325,800	gal
acre-ft	1234	m ³
acre-ft	43,560	cu ft
acre-ft/day	0.5042	cfs
acre-ft/day	0.01428	m ³ /sec
acre-ft/day	1.234×10 ⁶	liters/day
acre-ft/day	0.3258	mgd
acre-ft/day	226.3	gpm
cu ft	0.02832	m ³
cu ft	7.481	gal
cu ft	28.32	liters
cu ft (water)	62.43 (approx.)	lb
cu ft (water)	28.32 (approx.)	kg
cfs	1.983	acre-ft/day

CONVERSION FACTORS (Cont.)

<u>ENGLISH UNIT</u>	<u>MULTIPLIED BY</u>	<u>EQUALS</u>
cfs	.02832	m ³ /sec
cfs	2,446,000	liters/day
cfs	0.6463	mgd
cfs	448.8	gpm
ft	0.3048	m
ft	3.048×10 ⁻⁴	km
gal	0.1337	cu ft
gal	3.785	liters
gal	0.003785	m ³
gal (water)	8.345 (approx.)	lb
gal (water)	3.785 (approx.)	kg
gpm	0.002228	cfs
gpm	0.004419	acre-ft/day
gpm	6.308×10 ⁻⁵	m ³ /sec
gpm	5,450	liters/day
gpm	0.00144	mgd
in	2.540	cm
lb	0.4536	kg
lb (water)	0.01602 (approx.)	cu ft
lb (water)	0.1198	gal
lb/day	0.4536	kg/day
lb/hr	0.4536	kg/hr
lb/yr	0.4536	kg/yr
lb/mi ² -yr	0.1751	kg/km ² -yr

CONVERSION FACTORS (Cont.)

<u>ENGLISH UNIT</u>	<u>MULTIPLIED BY</u>	<u>EQUALS</u>
lb/acre-yr	112.1	kg/km ² -yr
mgd	1.547	cfs
mgd	3.069	acre-ft/day
mgd	694.4	gpm
mgd	0.04382	m ³ /sec
mi	1.609	km
mi ²	2.59	km ²
mi ²	2.59×10 ⁶	m ²

CONVERSION FACTORS (Cont.)

Abbreviations used:

cm	=	centimeter
cfs	=	cubic feet per second
cu ft	=	cubic foot
ft	=	foot
ft ²	=	square feet
gal	=	gallon
gm	=	gram
gpm	=	gallons per minute
hr	=	hour
in	=	inch
kg	=	kilogram
km	=	kilometer
km ²	=	square kilometer
lb	=	pound
m	=	meter
m ²	=	square meter
m ³	=	cubic meter
mgd	=	million gallons per day
mi	=	mile
mi ²	=	square mile
qt	=	quart
sec	=	second
yr	=	year